RISKS AND BENEFITS TO CATS OF FREE ROAMING VERSUS CONTAINMENT

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Declaration

I declare that no material contained in the thesis has been used in any other submission for an academic award at this or any other institution. I declare that the thesis is all my own original work, except where otherwise indicated.

Ethical approval

All protocols pertaining to this project were approved by the University of Lincoln Research Ethics Committee.

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Abstract

Free roaming domestic cats (*Felis silvestris catus*) are widespread around the world. Whether they are owned or not, their presence and management raises strong opinions between supporters of "cat independence", advocates of "cat safety" and defenders of wildlife, leading to suggestions that cats should have their freedom to roam outdoors restricted. The aim of this thesis was to get a precise understanding of the concepts of free roaming and containment in cats, their meaning for the relationship between cats and the society that they are living in, both from the cats' 'point of view' and the perceptions of their owners, and the impact on cat welfare. Using a variety of approaches including a survey, GPS tracking, behavioural tests and an owner-based questionnaire, we showed that although many people's perceptions about free roaming cats depended on their residential location and their ownership status, the risk of road traffic accidents was rated highly as a concern by people regardless of their residential location or cat ownership status. This perception was matched by the behaviour of free roaming cats themselves, who, regardless of their home location were observed to frequently engage in risky behaviour like frequent road crossing. This represents a high risk to their wellbeing and, combined with the other risks posed to cats that go outside, makes a clear case for the need to restrict the cat's roaming behaviour, in order to protect its welfare. Given the problems of an indoor only lifestyle, which may perhaps be greater than is widely recognised, there is a case for examining the impact on cat welfare of an effective containment system, that restricts the cat to the boundaries of its owner's property (both minimising risk to the cat and disruption to the community). Options for containment are limited, and little is currently known about their impact. Therefore I examined the impact of an electronic containment system that is widely thought to be effective but that also causes concern regarding its effect on cat welfare. This was the first research on such a system in cats, and I sought to establish if the welfare concerns were justified and outweighed by the potential benefits. First, I gathered initial information with a case series, and then I carried out a more comprehensive study with a larger sample of cats. The initial case series failed to establish clear evidence of a consistent negative impact on welfare. In the larger follow-on study, for the population studied, I found no evidence consistent with a long term negative impact of the electronic containment system on cat behaviour and welfare. Indeed, cats contained by the system interacted more with people, were more curious about novel objects and were no more sensitive to sudden noise than control cats, although whether these effects were due to the system or selection bias in the volunteers remains unknown.

Although many research questions have been addressed, unanswered questions remain, and directions for future research have been identified and are discussed.

Preface

Abstract

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Chapter One

General Introduction

During history and human development, the relationship between humans and non-human animals has evolved. Initially seen as prey or threats depending on the animal, some species were domesticated over time to be used as working animals, pets or for food provision (Larson and Fuller 2014). Since then, the relationship between humans and domestic animals has become more complex, the human perception of animals and their welfare being shaped by culture, religion and society (Miele et al. 2011), e.g. with new aspects of this relationship being highlighted in recent times, including animals as a source of social support (Bradley 2012) and for assistance (Wright et al. 2015).

1.1 Relationship between humans and domestic animals: responsibilities

Domestic animals are legally characterised as property worldwide (Yu 2008). Whether they are farm, companion (pets) or work animals, they are owned, either by private individual or enterprises or institutions such as laboratories. As such, domestic animal owners (who will be referred to as "owners" in the rest of the thesis) have two keys areas of responsibility: (1) to ensure the welfare of the animal(s) they own (Animal Welfare Act 2006), and (2) to address any problems their animal may cause (Animals Act 1971).

1.1.1 Animal Welfare

During the last four decades, public and scientific interest in animal welfare has risen exponentially. Starting from the concept that animals should be treated "humanely" and should not be exposed to "unnecessary suffering" (Francione 1996), nowadays it is recognised that animal welfare is a concept that needs to be addressed at every step of the animal's life, with all relevant stakeholders in society (i.e. the public, scientists, government and welfare organisations; Bayvel and Cross 2010).

The first way to approach and address potential welfare issues is to define precisely what "animal welfare" is. Historically, acceptable animal welfare has been defined as the absence of suffering or the absence of any negative physical or emotional component. In agreement with this line of thinking, the Five Freedoms were developed in 1965 (Brambell Committee Report 1965), and acceptable animal welfare was defined as an animal:

- Being free from hunger, thirst or inadequate food
- Being free from thermal and physical discomfort
- Being free from injuries or disease

- Being free from pain and distress
- Being free to express normal, species-specific behaviours

But this definition did not take into account the fact that welfare could also be about the animal experiencing positive emotions, and that the animal's ability to cope and react to environmental challenges could play an important part in its welfare (Ohl and van der Staay 2012). A more precise and exhaustive definition by Ohl and van der Staay (2012) would be:

"An individual is in a positive welfare state when it has the freedom adequately to react to

_ hunger, thirst or incorrect food;

_ thermal and physical discomfort;

_ injuries or diseases;

_ fear and chronic stress, and thus,

_ the freedom to display normal behavioural patterns that allow the animal to adapt to the demands of the prevailing environmental circumstances and enable it to reach a state that it perceives as positive."

This definition encompasses both the ability of the animal to adapt to external circumstances and emphasizes the importance of the animal's perception of its circumstances. It also means that as much as possible, the steps taken to ensure an animal's welfare must take into account not only the animal at a species' level, but also at a group and an individual's level. It also hints that the concept of positive welfare must include a mental component, i.e. the fact that the animal will feel positive emotions (Boissy et al. 2007). It widens the scope of what the "animal welfare" is, showing that the animal welfare research has to go beyond the fact that the animal is functioning satisfactorily, and has to take into account the potential of subjective experiences which will translate into emotions (Fraser et al. 1997). An animal may function satisfactorily and be in a good physical health, but this animal fails to adapt to its environment, then negative subjective emotions might arise and then compromise the animal's welfare. The animal welfare thus encompasses both the animal physical health and the emotions that are experienced; research starting to develop indirect ways of measuring emotions (Mendl et al 2010a).

If defining what “animal welfare” means is an initial prerequisite to achieving it, the second essential step is to find an adequate way to measure it, and the measure developed will depend on the understanding each researcher has of the concept. The first types of measures used were physical and biological measures, such as heart rate, temperature, prolactin and corticosteroids, but these measures do not necessarily co-vary, and the animal’s response is likely to depend on the nature of the experiment, its individual experience, the animal’s species, age and sex (Mason and Mendl 1993). Therefore these measures of welfare are not reliable in themselves and results must be carefully interpreted according to the context, and in conjunction with other measures.

Behaviour is also a useful tool for measuring welfare, and Stamp Dawkins (2004) argues that “assessing welfare can be approached by asking two key questions: 1) is the animal physically healthy and 2) does the animal have what it wants?”; the first question covering the physical aspect of welfare and the second question covering the mental/affective aspects of welfare. Her review makes a counterpoint to the case for the last ‘freedom’, i.e. expressing natural behaviour, arguing that some natural behaviours may be performed in response to a threat and that restriction in expressing the natural repertoire does not necessarily lead to poor welfare. Regarding what the animal wants, observing the placement of a group of animals in a defined space (Dawkins et al. 2003), performing a choice task and asking the animal to work for access may help determine what the animal wants, and thus identify ways to improve the animal’s environment. While theoretically this is a very valid point, it implies that measuring welfare using behaviour as a tool would be done mostly through experimentation, even if it is applied experimentation in a real life situation. This may not always be possible, especially if one wants to assess welfare on a large scale (e.g. several farms, kennels, rescue centres…). Another way of assessing welfare would be to make behaviour observations without manipulating the environment. Tackling all different aspects of these problems allows a start to the development of protocols to measure animal welfare, whether it is for farm animals (cattle, pigs and chicken) with for example the Welfare Quality protocol that assesses the welfare of groups of animals (Temple et al. 2011; Jurkovich et al. 2012; Tuyttens et al. 2015); for laboratory settings (Burman et al. 2007); for companion or work animals, where the protocols are centred on the individual with targeted situations (Christiansen and Forkman 2007; Ramos et al. 2013; Buckland et al. 2014; Soontag and Overall 2014). These protocols and ways of measuring welfare keep getting refined in order to encompass the latest research (with a recent focus on ways to measure emotions, for example: Mendl et al. 2010a) and to find a way to get the measures more practical, reducing them to their essence (e.g. simplifying the Welfare Quality Protocol: Andreasen et al. 2014; Heath et al. 2014). Following the latest scientific recommendations and monitoring the animal's response to changes in the environment seem to be the best way to ensure good welfare.

But as an owner, there is another responsibility, i.e. being responsible for any problems that animals belonging to them may cause to others.

1.1.2 Potential problems linked to the management of captive animals

Even with the recent advances in animal rights (e.g. the change of the French civil code to match the rural code defining the animal as a sentient being; Law of the 16th February 2015), animals are still considered as a property. The owner, whether it is a private individual, an enterprise or an institution, is thus responsible to a degree for any damage or problem the animal may cause, for example: health problems for animal bred for food, injuries due to an attack by an owned animal, destruction or deterioration of another person's property (UK: Animal Act 1971; USA: Animal Welfare Act 2013; France: Law 99-5 on free roaming and dangerous animals 1999).

In order to hold to this responsibility, and depending on the use intended for the animal, the owner must be aware of the animal's location and restrain its freedom to roam. For the purpose of this thesis, the term "containment" applied to an animal will define the means taken to restrain or limit the freedom of the animal to roam, and can be represented by fencing, an enclosure, or, in general, keeping the animal in a place where it cannot be let out without the owner's and the keeper's consent, for example in a locked house or a kennel. This way, the animal stays on the owner's or the keeper's property.

1.2 Management of captive animals: degrees of containment

Most captive animal management includes a degree of containment, from a high degree of containment – for example the cages of intensively farmed laying hens - to a minimal degree of containment, for example, the extensive management of the highland cattle or the horses roaming in the 219 square miles of the New Forest National Park (England). Containment is usually put in place to keep the animal on its registered owner's or keeper's property, and may have benefits and drawbacks.

1.2.1 Containment: potential benefits and drawbacks

1.2.1.1 Benefits

Free roaming animals, whether they are wildlife (Steiner et al. 2014; Zuberogoitia et al. 2015) or domestic animals, owned or not (Massei and Miller 2013; Rochlitz 2003a) can be injured in animal-vehicle collisions. Thus the first benefit of having an animal properly contained is to ensure this animal's safety from injuries due to vehicle collision, whether the vehicle is a car or a train (Babińska-Werka et al. 2015). Animals can also be predated upon (Biswas et al. 2006), and while fencing is not always a hundred percent efficient (Moberly et al. 2004), providing shelter with housing helps reduce the predator's access and thus the risk of predation (Zhang et al. 2002). The third benefit of the owned animal being contained is that the animal's location is known, and that the premises can be managed to a high standard, so that the animal's needs (e.g. food, water, shelter, medication) are provided for and the risk of diseases can be reduced: for example, pasture management in the case of horses can reduce the risk of helminth infestation (Corbett et al. 2014). Finally, another benefit can be a social benefit: for the males, breeding does not need to be preceded by inter-male competition and the associated risks (for example in the fallow deer; Bartŏs et al. 2007).

But the way animals are contained has to be carefully thought through in order not to impact negatively on their welfare.

1.2.1.2 Drawbacks

The first type of drawback will be the direct physical drawbacks linked to the type of containment used. Being contained will, in most cases, reduce the amount of daily exercise that the animal may have, leading to unwanted consequences such as obesity (for example in cats: Rowe et al. 2015 and in dogs: Handl and Iben 2012), which is associated with a variety of serious diseases: diabetes mellitus, cardiovascular problems, and osteoarthritis (German 2006; Passlack and Zentek 2014) leading to a reduced life expectancy. Another physical drawback of being contained is the potential for injuries due to inadequate housing, for example the design of bedding areas for dairy cows where hock injuries are increasing when the bedding is sawdust or when the stalls are faecally contaminated, or when the cows do not have access to pasture during the dry period (Barrientos et al. 2013) and for pigs, where increasing stocking density and group size may result in tail and hindquarters skin lesions (Vermeer et al. 2014). Moreover, being contained increases the risk of exposure to hazards associated with the containment area, if this area is not adequately checked for safety, such as bare electric cables in the home or exposure to flame retardants which may increase the risk of hyperthyroidism in cats (Norrgran et al. 2015).

The second type of drawback will be the behavioural and psychological drawbacks of being contained. Indeed, being contained restrains the possibility of wandering that may be a normal part of the behavioural repertoire of the species (for example ground pecking in hens Riber et al. 2007; grazing behaviour in horses Ferreira et al. 2013), which could lead to poor welfare. In that case, not only the space allowed but the layout of the contained space may be of high importance, for example birds were more distributed under and near trees and open areas were avoided in Dawkins et al. (2003). Furthermore, containment submits the animal to entire control by humans, which may have several consequences. The carer may inadvertently compromise welfare and trigger frustration related behaviour leading to injuries, whatever approach to welfare is chosen. For example, laying hens may display feather pecking behaviour (Rodenburg et al. 2005) and/or cannibalism depending on the type of housing (Weitzenburger et al. 2005), even if the causes of feather-pecking appear multi-factorial (nutrition being a factor of influence, Kjaer and Bessei 2013). Stabled horses may display frustration behaviour depending on the eating schedule (Ninomiya et al. 2004) or the type of housing (Ninomiya et al. 2008). Dog housing in kennels may be associated with poor welfare (Taylor and Mills 2007), and cats have to develop a way to cope when they are confined indoors, whether it is a temporary or a permanent situation (Jongman 2007; Stella et al. 2014; Rehnberg et al. 2015). For most of the previous examples, containment is one aspect of the problem, but not likely to be sole cause. However, it is the primary fact of being contained that deprives the animal of the opportunity to act in order to respond to a challenge (for example not being able to forage if the food is distributed later than usual). In a contained environment, the animal has less control over the events happening, and the predictability of the schedule depends on the carers. Several studies show that predictability of events, whether they are aversive or positive, enhanced the animal's welfare in most of the cases, whether the measures of welfare relies on physiological or behavioural (preference tasks) measures (Basset and Buchanan Smith 2007 for a review on predictability and control). Moreover, signalled predictability, i.e. where the event is preceded by a signal, may be the animal's preference. For example, in sheep, the predictability of a sudden event appeared to lower the response to the event (startle and cardiac response, Greiveldinger et al. 2007); even if several exposures are needed for the animals to learn the association between events. In some cases, unpredictability may enhance welfare, for example spatial and temporal unpredictability of feeding is used as an enrichment tool to increase exploration by captive animals (Jenny and Schmid 2002 for Amur tiger; Nogueira et al. 2011 for farmed collar peccary). In addition, control and predictability are often two faces of the same coin, because predictability of an event may allow a degree of control over it by the animal, in the way that it can prepare its response to the event. Even in case of an aversive event, having control over the event seems to decrease the stress caused by it (Greiveldinger et al. 2009). However, in the case where the animal has no control and no way to cope, the predictability may increase the negative anticipation of the event.

In addition to the control by humans of the space allowed, layout and schedule of events, being contained also means that, for social species, individuals may have a reduced choice of conspecifics. In several species, research shows that the social composition of the group is very important (Boissy 2012 in farm animals) and changes in the social structure may lead to poor welfare (Li and Johnson 2009 for pigs; Hovland et al. 2010 for farmed foxes; Meyer et al. 2010 for sheep). Therefore mixing animals from different groups previously formed (i.e. where affinities developed) may not be a good idea and if it cannot be avoided, steps must be taken to minimise the possibility of agonistic interactions between unfamiliar animals.

In conclusion, while there may be some benefits such as the reliable provision of food, water and shelter, containment inevitably deprives the animal of some control of its environment and reduces the possible ways to cope with an aversive event, which can lead to compromised welfare. Therefore the human decision to contain an animal must be taken while taking into account the individuality of each animal occupant so the contained area can be designed to maximise the animal's welfare.

Different compromises in containment are made according to the purpose of keeping the animal, e.g. an animal that is bred and raised for food, or other products (milk, wool), may not be contained the same way as a companion, lab or work animal.

1.2.2 Farm animals

A farm animal is typically an animal raised in order to produce food or other product for the purpose of human consumption and use, such as cattle, sheep, pigs, poultry, rabbits and fish. In the case of farm animals in industrialised countries, their management can range from intensive to extensive, therefore varying considerably in their degree and type of containment, for example from indoor confined feedlots (Grooms and Kroll 2015) to a year round extensive management of highland cattle (Hejcman et al. 2005). This degree and type of containment may have an impact on the animal welfare, e.g. indoor feedlots increase the possibility of lameness (Grooms and Kroll 2015) and also the risk of disease spread (Choi et al. 2005). But a free ranging environment is not without risk, for example free ranging pigs display more osteochondrosis in the joints than confined pigs (Engelsen Etterlin et al. 2013). However, this is a good example of the difference between health and welfare: health being defined here as a general good physical state of the animal, a healthy animal being an animal that is not affected by any pathology; whereas the welfare of the animal encompasses not only the physical health, but also a mental component (affective state), and the consequences of the animal's physical health on this affective state. In that specific case, a more recent study by the same researchers shows that lameness is not increased in those pigs (Engelsen Etterlin et al. 2015) suggesting that if the free range management of fattening pigs may compromise the health of their joints, it does not actually cause pain, so the welfare may not be compromised. Furthermore, in beef cattle, when both environments (feedlot and pasture) are available, animals use both environments but show a preference for the pasture (Lee et al. 2013).

Where outdoor grazing is concerned, the type of containment is also variable, from solid fences made of wood or wood and wire, to electric fences. Electric fences are more manageable and allow a more flexible management of pasture, but their potential effect on welfare may be greater than with traditional fences. While animals can sustain injuries if they crash into fences (Kuhn and Traub 2012 for example), with the electric fences, if the power is not cut, the animal receives electric shocks. Early studies investigated the electric fences' efficacy (Poole et al. 2002; Goetsch et al. 2012) but also their impact on animal welfare. Regarding wildlife, the effect seems to be transitory and not affect the overall welfare (Poole and McKillop 1999; McKillop and Wilson 1999) but the fact that wildlife is involved renders the close monitoring of individual animals difficult. In the case of farm animals, training is effective (Martiskainen et al. 2008), and the effect of the shock has been compared in cattle to being restrained in a crush (Lee et al. 2008) but this does not indicate if or how much welfare could be compromised, even if the effect of the shock seems transitory. In farmed red deer, the change in behaviour was attributed more to the fence’s novelty than to the type of fence (Goddard et al. 2001) but pacing was still greater with the electric fence. Receiving an electric shock seems to elicit a stronger behavioural response which were, specifically, attempts at fleeing (tossing head whilst in the crush and flight time; Lee et al. 2008) than comparative treatments. This is not sufficient to conclude on an overall effect on welfare since in containment with electric fences, the animal may not receive a shock if it stays clear of the fence. It would be interesting to compare in cattle the behaviour of the same animals in different managements (electric fence versus traditional fence), as it has been done with horses (Moors et al. 2010; Glauser et al. 2015, see companion animals).

1.2.3 Laboratory animals

Laboratory animals are used in very diverse areas: for example experimental medicine to test the effect of a drug, animal models of a disease, or to study food preferences (Araujo et al. 2004; Nazem et al. 2015). They are a specific case as their environment and the environment’s management are highly regulated, the environment itself being very homogenous (Animal Scientific Procedure Act 1986). Again it is not solely the containment aspect that is involved, but the layout of the contained area and the husbandry procedures. Research is carried out to investigate the effect of these aspects on laboratory animal welfare: For example, witnessing husbandry procedures affects the behaviour and welfare of rats (Abou-Ismail et al. 2015) and enriched housing may generate a positive affective state in rats (Brydges et al. 2011). The more the animal is contained and completely under human control, the more precise the containment area and human interaction with the animal has to be in order not to compromise welfare (see playful handling with rats, Cloutier et al. 2015).

1.2.4 Companion and work animals

A companion animal is an owned animal kept for company or leisure, while a working animal will be kept in order to help its owner during work. Companion animals include mammals (for example dogs, cats, equids, rabbits, and ferrets), reptiles, fish and birds, while work animals will include for example, certain dogs and equids. Dogs can be used as guide dogs, police and military dogs, search and rescue dogs, and for security. Horses and donkeys can be used to pull carriages, carry weight/burdens, or used professionally in entertainment (e.g. horse racing, show jumping).

When kept as pets, reptiles, fish and birds are contained *de facto* (either in the home or in a specific containment outside) and provided with specific housing that meet their needs along with some degree of spatial restriction, for example vivaria and aquaria for reptiles and fish (Pees et al. 2014), and cages or aviaries for birds (Hawkins 2010). The case for mammals is slightly different; their degree of containment depending on what the owner is using them for. Horses can be stabled or free to roam within the boundaries of a field, or can be ridden by their owners outside those boundaries. Dogs and cats live in their owner’s house or in kennels or catteries, but dogs can also be walked on or off lead while they are under the control of their owners. Pet rodents and rabbits may be kept in cages or be free to roam in the owner’s property. All those types of containment can have an influence on the animal’s welfare, and, as for farm animals, recommendations are made to adapt the containment area to the animal’s welfare, not only about the layout of the housing itself, but also about the enrichment provided, e.g. for cats (Rochlitz 2005; Ellis 2009); dogs (Conley et al. 2014; Hewison et al. 2014) and horses (Hoffman et al. 2012). Horses are similar to farm animals in the fact that even if they are kept in stables, some of the species has the possibility to graze outside. In this case, the owner or keeper has to make a decision about the question of the specific containment type, i.e. traditional or electric fences. As mentioned earlier, studies investigating horse welfare compared electric fences with more traditional settings, e.g. wooden fences and metal tube fences (Moors et al. 2010; Glauser et al. 2015) by putting individual horses in selected areas, each with a specific type of fencing; and recording behaviour, use of the area, and physiological measures. Although no physiological measures of stress such as salivary cortisol and heart rate showed a difference between electric and traditional fence, the utilisation of the surface area by the horse was smaller with electric fences, and time spent near the fences was also shorter with small and electric fenced paddocks. It is also stated that electric fences decreased the social contact between horses from paddock to paddock which, in a gregarious species could be detrimental to welfare. In the study comparing size of the paddock as well as type of fence (Glauser et al. 2015), the experimental phase lasted 90 min and the horse was also alone. For future research, it would be interesting to compare wooden pasture and electric fenced pasture with the same group of horses over time, which would give valuable indication on the overall horse welfare regarding electric fencing.

The similarity between farm, companion and work animals is that their freedom is limited by their owner's decision and that if they happen to be on another person's property, it is potentially an offence. The cat is an exceptional case in that regard. At least in Europe and in the USA, the law recognises that cats are animals that may wander and that they may be found at large on public property (USA) or on private property that is not their owner's property, without the owner being liable as long as the cat expresses normal behaviour (Animal Act 2006; Cat and the Law, Nurse and Ryland, The Cat Group 2014). The cat is thus the one and only owned animal for which free roaming is considered acceptable by law. That makes the species a specific case, worth investigating in regard to its management.

1.3 The specific case of the cat

Cats are very popular pets; the number of cats kept as pets around the world is estimated to 220 million, not including stray cats (http://www.ifaheurope.org/companion-animals/about-pets.html). In the European Union, cats kept as pets are around 66 million (Facts and figures FEDIAF 2012). A 2007 survey estimated the population of owned cats in the UK to be between 9400 000 and 11200 000 (Murray et al. 2010) while the PDSA (People's Dispensary for Sick Animals) Animal Wellbeing Survey report (or PAWS report) estimated the cat population in the UK at 11.1 million in 2015. The difference may be explained by the difference in samples in the two studies, Murray et al. 2010 having a sample of 2980 households and the PAWS report 12 334 cat owners; or by the sampling method used (telephone questionnaire for Murray et al. 2010; online questionnaire for the public and face to face interview of professionals for the PAWS report). Here, we will approach cat management from the specific point of containment, not including management subjects such as veterinary care or neutering. Cat management depends on the perception of cats by society and the specific country they are living in.

1.3.1 Management of cats around the world

Cats are believed to be independent animals (Turner and Bateson 2000; Toukhsati et al. 2007) but their management depends on the way their presence interacts with the environment. They are considered as a pest in some areas: For example, on Christmas Island a program is put in place to keep control of cat numbers, in order to conserve biodiversity (Algar et al. 2014). In countries like New Zealand and Australia, cats are also considered a threat to native wildlife (Recio et al. 2010), to species such as the black fronted tern (*Sterna albostriata;* Keedwell 2005) which is considered endangered on the International Union for Conservation of Nature (IUCN) Red list 2015 (http://www.iucnredlist.org/details/22694750/0). Public attitude in these countries favours cat containment, cat curfews, i.e. the need to keep the cat indoors at night enforced by law (Toukhsati et al. 2012) and the establishment of buffer zones to protect wildlife (Lilith et al. 2008; Metsers et al. 2010). While it is clear that cat predation poses a threat to wildlife (Woods et al. 2003; Loss et al. 2013), it is a controversial subject because other causes like human occupation and pollution are much more difficult to investigate. Most of the studies suggest that the bigger threat is unmanaged populations of feral cats rather than owned cats (Recio et al. 2010, Loss et al. 2013). Also, a study suggests that cat predation could represent a compensatory form of mortality (Baker et al. 2008), cats killing birds that are in poor condition that would otherwise have died for other reasons. Furthermore, a recent study in owned cats showed that less than 50% of them actually kill prey (Loyd et al. 2013) and a study comparing a no-cat zone to an unregulated zone showed that the presence of wildlife might be more related to vegetation density than to the restriction of cat presence (Lilith et al. 2010) – although these factors could interact. This threat to wildlife is one of the possible influences on cat management around the world and it depends on the country. In the USA, around 60% of cats are kept indoors (Harbison et al. 2002; Clancy et al. 2003) and the owner's decision to let a cat have outdoor access appears to be multifactorial, including the source of the cat (shelter or stray) and the time of day (more cats restricted at night) (Clancy et al. 2003). In Europe, we do not have estimates of the percentage of cats that have outdoor access.

1.3.2 Cat management in the UK

The PAWS report 2015 is a large survey (33 283 people surveyed comprising 12 334 cat owners) in the UK. It gives insights into the cat population and the different trends in cat keeping. According to this report, in 2015, 24% of cats live an indoor-only life, which is less than in the United States but a number that is increasing over time (only 15% of cats were indoor only in 2011, PAWS report 2015). This trend might show that beliefs about cat management may be changing, at least in the UK.

1.3.3 Cat containment: the indoor/outdoor debate

As stated earlier, many people believe that cats are independent animals that need to go outside in order to express natural behaviours (Turner and Bateson 2000; Jongman 2007). It does not seem to be the belief that changes, but the respective weight given to this belief against others, which are that cats are natural predators and a threat to wildlife (Recio et al. 2010, Peterson et al. 2012) and can be a nuisance for neighbours by soiling gardens, making excessive noise (Toukhsati et al. 2012; Gunther et al. 2015). Allowing a cat to have outdoor access is also not without risk: Road traffic accidents appears to be the fourth most common cause of death for cats after old age, cancer and renal failure in the UK, according to a questionnaire with 182 answers developed by Rochlitz et al. (2001), which gives us a proportion but perhaps not a number to rely on. Moreover, half of cats' unexpected deaths in Canada may be due to a road traffic accident (Olsen and Allen 2001). The only number we have in the UK is based on the Pet Plan insurance company estimation: the number of cats killed on UK roads in 2006 would be around 230,000. Further research is needed to ascertain the reliability of this number, which is difficult as a cat death is not necessarily reported to the authorities, as it is not a legal requirement (Road Traffic Act 1988, and https://www.gov.uk/report-dead-animal). Outdoor cats can also catch transmittable diseases (Hosie et al. 2009; Lutz et al. 2009), be poisoned (Berny et al. 2010) or injured (Kilic and Derincegoz 2012, RSPCA prosecution report 2013). In certain countries like the USA, cats also have predators like coyotes which are also a risk to cat safety. Research has studied the behaviour of outdoor cats and their links to the environment in many ways, such as measuring home range size, activity patterns and impact on wildlife (Edwards et al. 2001, Van Heezik et al. 2010, Horn et al. 2011, Wierzbowska et al. 2012) and found that home range of feral cats were greater than owned cats, and that the pattern of activity for owned cats followed their owner's pattern of activity. People's perceptions regarding free roaming cats, whether they are owned or feral have been studied with regards to neutering status (Finkel and Terkel 2012), veterinary care (Murray and Gruffydd-Jones 2012) and containment (Toukhsati et al. 2012). But all these studies have focused on one or several groups of cats/cat owners in one location, and focused on the problems that outdoor cats can cause for the community or to the environment they are living in. Surprisingly little research has explored people's perceptions about benefits, risks and problems linked to free roaming cats, explored the potential differences between communities concerning these perceptions or mapped these perceptions to the actual behaviour of cats within the same environment - an area of research that could be the ground for policies leading to resolving and pacifying neighbourhood conflict due to free roaming cats.

Taking into account the risks previously mentioned and the need for cat safety, one approach could be to keep the cat solely indoors, but that may also not be the ideal management approach. A study reviewing the results of case control studies about diseases common in cats and comparing the occurrence of the disease to the opportunity for outdoor access found that being an indoor only cat can increase the risk of obesity, Feline Urologic Syndrome, dental disease and decreased activity (Buffington 2002). More recently, a potential link between fire retardants in furniture and cat hyperthyroidism has been reported (Norrgran et al. 2015). In addition, being kept indoors can trigger behavioural problems, such as inappropriate toileting or furniture scratching, which can lead to the relinquishment of cat to a shelter (Jongman 2007, Pereira et al. 2014).

A compromise must therefore be found between meeting the cat's needs and achieving a high standard of welfare, and keeping the cat safe whilst minimising the problems that the cat can cause. This compromise could be to contain the cat not to the indoor space, but to allow the access to a safe and sufficient outdoor space, in order to fulfil all the cat's needs. Whilst it might not mitigate all potential risks, it would greatly decrease the likelihood of most of them. Several types of containment system are available for cats: cat enclosure designed and built to the owner's specifications, diverse types of fencing that claim to prevent the cat from getting out of its owner's property (for example rolling tubes put on an existing fence, Katzecure®, wire to put on an existing fence Purrfect Fence®) and also a supervised access outdoor, with the cat on a lead. Most cat enclosures will be enriched with shelves to perch on, place to hide, lie down and toys but will be limited in size and not incorporate the entire owner's property, so will still be a restriction of the space available. The use of containment fencing is an interesting approach but may not always be possible due to planning restriction or neighbour complaints due to the aesthetic aspect of the fencing. Keeping the cat on a lead while outside allows complete supervision and control for the owners but clearly restrains considerably the cat's freedom and time outside.

Another approach has been developed in the last forty years: electronic 'virtual' fencing. First developed by Peck in 1973 mainly for dogs and cats, patents were also submitted for cattle (Umstatter 2011). This system relies on a wire, either buried in the ground or attached to an existing fence, which emits a low frequency radio signal. The animal wears a receiver around its neck. If the animal approaches the boundary area defined by the wire, a warning sound is emitted. If the animal continues its approach (i.e. does not remove itself from the boundary area), the collar emits an electric ‘correction’ in the form of an electric shock, aimed at preventing the animal from crossing the boundary. Although the animal may receive an electric shock, the system is different from electric fencing where it is the fence that is electrified by means of a wire, while in electronic virtual fencing the electricity is produced by the collar and only in specific circumstances. Electric fencing is widely accepted in cattle (CAWC report 2012); however the electronic containment systems (e.g. freedom fence®, dog fence®) as a part of all electric pulse training aids (EPTA) have raised strong opinions and concerns about potential welfare problems associated to their use. In Wales, a ban on all electric aids including the virtual fencing system is in force (The Animal Welfare (Electronic collars) (Wales) Regulations 2010). Regarding virtual fencing, early studies by Tibbs et al. (1995) and Tiedemann et al. (1999) explored its effect on cattle, the receiver worn on an ear tag. Both studies showed weight loss in the treatment group that could have been attributed to virtual fencing, but authors attributed this to the difference in diet and in training and handling procedures. This interpretation is certainly a possibility but before such potential impacts on welfare are disregarded, further research is needed with animals fed on the same diet or the same calorie ratio per day to exclude the possibility that the weight loss or relative weight gain is due to the electronic fencing. Further research has been done on cattle and sheep (Lee et al. 2009; Jouven et al. 2012; Markus et al. 2014; Umstatter et al. 2015) but has focused more on the efficiency of the system rather than on the animal’s welfare (see Chapter 7 for details).

Regarding companion animals and the use of electric aids, an extensive review of the literature has been done by Mills et al. (CAWC report 2012): “ten publications in direct relevance to the use of EPTA in dogs were found and none in other companion animal species”, none of which related to boundary fence systems. Nonetheless, the report concludes that distinction should be made between “devices which are activated by the animal’s behaviour and those which depends on some other party to discharge the stimulus”, because a device that is triggered by the animal’s behaviour delivers the same correction consistently associated to the targeted behaviour, allowing the animal itself to make the association between the behaviour and the correction. The animal is then being able to learn to modify its behaviour and in control of the situation. When the device depends on some other party to discharge the stimulus, this third party may not discharge the stimulus at the exact time that enables efficient learning, leading the animal to be confused and stressed by the unpredictability of the correction. The electronic containment system uses a device triggered by the animal's own behaviour, which enables the animal to learn efficiently to avoid the boundary wire. But, as yet there are no peer-reviewed publications on how cats respond to this system; how learning proceeds with respect to the boundary, how long the learning lasts and what happens if a strong attraction occurs to encourage crossing of the boundary (e.g. a prey escaping from the cat by crossing the boundary). We also have no idea if being restrained in this way triggers frustration or some other form of distress, nor about the effect of the electric correction itself, whether it happens once or several times. Therefore, research is necessary about the use of virtual fencing and its potential effect on welfare, especially in cats.

1.4 Aims of the thesis

The overall aim of this thesis was therefore to get a precise understanding of the concepts of free roaming and containment in cats, their meaning for the relationship between cats and the society they are living in. This was done by first investigating people's beliefs about the benefits, risks and problems linked to free roaming cats depending on where they live and whether they own a cat or not (Chapter 2). Secondly, by discovering where cats go when they are outside and if they engage in risk taking behaviour like crossing roads (Chapters 3 and 4). Thirdly, to review the risks cats are exposed to when they are outdoors (Chapter 5). And finally, to determine if an electronic containment system had an impact on cat welfare (Chapters 6, 7 and 8).

Chapter Two

People's perception of benefits, risks and problems linked to free roaming cats

2.1 Introduction

Cats live in a human society, in which perception of them and their welfare is shaped by culture and beliefs (Miele et al. 2011). Cat management is partially regulated by the law (Animals Act 1971; Animal Welfare Act 2006) but caring for cats and ultimately enforcing policies is largely the responsibility of members of the community rather than the police who has other priorities. Therefore the way people perceive the diverse issues involved in the management of cats (e.g. neutering, vaccination, allowing a cat to go outside or not), is of importance when considering the welfare priorities. People's perceptions are often explored by means of a questionnaire (Boulhosa and Azevedo 2015; Zito et al. 2015); they may yield different information to a face to face interview (van der Poel et al. 2013) and the shorter questionnaires are the better completion rate and cooperation are likely to be (Holbrook et al. 2003). Focusing on cat management issues (such as people's attitudes towards free roaming cats, containment, neutering, and characteristics of cat ownership), completion rates for self-completion questionnaires either sent by post, or telephone, or given by hand has been reported to be around 30% (Murray et al. 2009; Toribio et al. 2009; Toukhsati et al. 2007, 2012). When the completion rate is higher (e.g. 54.3% Finkler and Terkel 2012) there is usually a special circumstance such as distribution at veterinary clinics, where the respondents are more likely to want to cooperate because they have a special relationship with the clinic. Another parameter to take into account is the possibility of self-selection bias. This may be a feature of the distribution method e.g. Finkler and Terkel (2012) included only cat owners who go to a veterinarian clinic or an animal shelter, or the respondents, i.e. people who actually respond to a questionnaire often have more interest in the issue surveyed (Bornehag et al. 2006). In either case, this bias affects the conclusions that can be drawn from the results. Ways of tackling this problem include gathering information (i.e. that is available such as socio-economic factors of an area) on a larger population than the targeted one (i.e. the one that will answer to the potentially longer survey) and comparing the targeted population against the larger one (Bornehag et al. 2006); being aware of what socio-economic factors may influence responses (Perkins-Porras et al. 2006), and carefully interpreting results taking into account the respondent population.

Regarding cats and management issues, overpopulation of cats that are feral or semi-owned is a real issue in several countries. People have been surveyed about neutering (Murray et al. 2009; Toribio et al. 2009; Finkler and Terkel 2012), semi-ownership and its consequence (Toukhsati et al. 2007; Zito et al. 2015). Although neutering programs lead to a sizable percentage of cats being neutered, for example in the UK (Murray et al. 2009); the willingness to have a cat neutered may depend on income and education (Finkler and Terkel 2012). Even when neutering is carried out, it may be after the female cat has had a litter, and thus contributed to the increase of the cat population. This is a serious issue, the number of cats being directly related to the number of free roaming cats and potential issues they may cause. Furthermore, semi-ownership is linked to frequent feeding and positive feelings towards cats (Toukhsati et al. 2007), but semi-owners do not always take steps to have the cat they care about neutered (Zito et al. 2015). Therefore semi-ownership also increases the number of free roaming cats. Focusing on free roaming cats and the problems they may cause, attitudes towards free roaming cats and containment (Toukhsati et al. 2012; Gunaseelan et al. 2013) were studied, finding that there is global support for cat containment in Australia at least at night, but that primary reasons for containing cats were very different for cat owners and non-cat owners. Cat owners were more concerned for their cat safety and non-cat owners about the problems free roaming cats can cause, such as neighbourhood nuisance. Attitude towards containment did not vary depending on the residential location (Toukhsati et al. 2012). However, more rural inhabitants did own at least a cat, maybe for pest control purpose, so the perceptions they have about free roaming cats may be very different from city inhabitants (Toukhsati et al. 2012). All studies previously quoted focused on people's perceptions about neutering, overpopulation and the problems cats can cause. A recent review was published on the disease risk related to cat behaviour and management options (Lepczyk et al. 2015) but it did not consider people's perceptions. Therefore there is an opportunity to explore more in depth people's perceptions not only on risks for cats going outside and the problems they can cause with the purpose of managing cats, but also to explore benefits that may exist from cats going outside and the benefits that free roaming cats may provide to the community they are living in. The purpose of the current study was to survey and to compare the perceptions of people regarding the benefits, risks and problems linked to free roaming cats depending on their status (cat owner versus non cat owner, city inhabitants versus village inhabitants). I predicted that village inhabitants would be more concerned about wildlife issues and pest control than city inhabitants, and that cat owners would identify more benefits to allowing a cat outside, and be more concerned about cat safety than non-cat owners.

2.2 Methods

2.2.1 Study areas

To explore the differences between urban and rural communities about their perceptions of the benefits, risks and problems linked to free roaming outdoor cats, I surveyed two distinct geographic areas. Both areas were chosen to compare two densities of urban habitat, a high density housing area (85.82 houses per hectare) crossed by a busy road and a low density housing area with big gardens (14.85 houses per hectare), also crossed by a busy road and surrounded by countryside. The two specific urban settings were of approximately 500 houses each, one in the city of Lincoln (Lincolnshire) and one in the nearby village of Dunholme (Lincolnshire). The details of the two areas are shown in Figure 2.1.

A

B Lincoln 500 houses

58264 square metre

Dunholme 500 houses

336680 square metre

Figure 2.1: **A** Two areas on a map. **B** Detail of the two areas covering 500 houses.

2.2.2 Questionnaire

Items were generated from the content of interviews undertaken to redundancy by a co-worker (Mahon unpublished data). The questionnaire was designed to be short and was refined after a comprehension assessment with volunteers to ensure that it was understandable. Two versions of the questionnaire were designed; one for cat owners and one for non-cat owners (see Appendix 1). Both versions were included in the envelope. The questionnaire was divided into three parts: the first part established the address and ownership status, and if the person was a cat lover. The second part comprised questions about the sight of free roaming cats for non-cat owners, and some additional questions about the free roaming behaviour of their cat for cat owners. Finally the third part included questions about perceptions of benefits, risks and problems linked to cats free roaming outside the confines of their owner's property. The items were of a defined choice closed format design, with multiple answers as an option. The items were designed to force people to prioritise a specific number of responses in relation to their opinions. An example item is shown in Figure 2.2. This chapter focuses on the results and analysis of the third part of the questionnaire, as this was the part that allows direct comparison between owners and non-owners.

A03. In your opinion, what are the **two most important benefits** to a cat from being allowed to go outside ?

☐ I think there are no benefits to a cat from being allowed to go outside.
☐ Freedom to express natural behaviour
☐ Opportunities to hunt
☐ Exercise
☐ Interactions with humans
☐ Interactions with other cats
☐ Interactions with other animals
☐ Interesting experiences for the cat
☐ Other, please specify : ____________________

Figure 2.2: Sample item on the benefits to a cat from being allowed outside.

2.2.3 Survey distribution

Before sending out the questionnaire, a press release was sent to local newspapers targeting the areas of interest, in order to attract the residents' attention. Then, the survey was delivered by hand to each address with a return postage paid envelope and details of the door to door follow up that would occur four weeks after the survey had been delivered. The follow up was conducted twice, once in the morning and once in the afternoon in order to maximize the response rate.

2.2.4 Data analysis

For every item of the questionnaire regarding benefits, risks and problems linked to free roaming cats, respondents were asked to choose two or three answers. This gave a frequency for responses prioritised by people that could be categorised according to their status (village versus city inhabitant, cat owner versus non cat owner). When an answer box was ticked, it translated into a “Yes” answer and when it was not ticked, it translated into a “No” answer. This allowed me to fill in two by two tables (housing area versus yes/no answer) for each answer. I then compared these frequencies by means of a chi square test with one degree of freedom in each case, performed by SPSS software (version 19). For the questions where only one answer is possible (for example “is your cat neutered? Yes/No), the level of significance was set at $p<0.05$. But for questions regarding benefits, links and problems linked to free roaming cats, in order to account for the multiple testing, we divided the significance level (i.e. 0.05) by the number of tests performed for each question. For example, for the question presented in Figure 2.2, nine potential options were offered (including the answer “other”) for comparing frequency of response between the demographic groups, so the level of significance for this item was 0.05/9=0.00556. In Table 2.1 are presented the level of significance for each question.

Question	Level of significance (Bonferroni correction)
In your opinion, what are the **two most important benefits** to a cat from being allowed to go outside?	**0.00556**
In your opinion, what are the **three main risks to cats** from being allowed to go outside?	**0.00625**
In your opinion, what are the **two most important benefits** for the community of cats in the neighbourhood?	**0.00625**
In your opinion, what are the **three main problems** for the community of cats in the neighbourhood?	**0.00454**

Table 2.1: Level of significance after Bonferroni correction depending on the question

2.3. Results

2.3.1 General

The survey was distributed to 500 houses in each area (city and village). It yielded 150 respondents in the city area (32.6%; 105 non owners and 45 owners) and 222 respondents in the rural area (46.25%; 148 non owners, 74 owners); the overall completion rate was 37.2%. For the cat owning population, in the city the multi-cat household proportion was 33.3% of respondents (15/45) and in the village 27.02 % (20/74). Percentage of neutered cats was significantly higher in the village location (95.9%) than in the city location (84.1%), chi square (1)=4.890 p=0.033. Cat sightings in the neighbourhood was significantly more frequent in the city (e.g. "more than ten times per week" city 48,7% versus village 32.1%; chi square (3)=14.103; p=0.003). For the general population of respondents, the most frequent benefits, risks and problems are presented in Table 2.2.

Item	Most frequent answers	Frequencies (%)
Benefits for the cat	"freedom to express natural behaviour" "exercise"	62.9 62.1
Risks for the cat	"road traffic accident" "problematic encounters with animals"	95.9 48.4
Benefits for the community	"provides enjoyment for those who like cats" "pest control"	45.5 40.9
Problems for the community	"unwanted toileting" "unwanted mating" "killing wildlife"	90.1 52.1 39.7

Table 2.2: Most frequent answers in the whole population of respondents surveyed, frequencies in percentages.

2.3.2 City versus village inhabitants

2.3.2.1 Benefits for the cats to being allowed outside and for the community

Frequencies of answers per benefit and per location are presented in Table 2.3.

Benefit for the cat	City (%)	Village (%)
I think there are no benefits to a cat from being allowed to go outside	14.1	9.1
Freedom to express natural behaviour	61.1	64.1
Opportunities to hunt	12.1	16.4
Exercise	59.7	63.6
Interactions with humans	3.4	1.4
Interactions with other cats	16.8	5.5
Interactions with other animals	4	3.2
Interesting experiences for the cat	21.5	23.2
Benefit for the community	City (%)	Village (%)
I think there are no benefits to the community from cats in the neighbourhood	24.2	19.1
Pest control	31.5	47.3
Acts as a focus for neighbourhood interaction	12.1	12.3
Provides enjoyment for those who like cats	46.3	45
Helps people learn about certain aspects of nature	7.4	5.5
Provides a source of routine to people's life	12.1	5
Gives people something special to care for	33.6	35.5

Table 2.3: Frequencies of answers (%) per benefit and per location.

City inhabitants quoted "interaction with other cats" as a benefit for the cat significantly more than village inhabitants (chi square (1) = 12.627; $p<0.0005$), and village inhabitants quoted "pest control" as a benefit for the community significantly more than city inhabitants (chi square (1) = 9.091; $p=0.003$). There was no significant difference between the city and village inhabitants for the two most quoted benefits for the cat: "freedom to express natural behaviour" and "exercise" (see Figure 2.3).

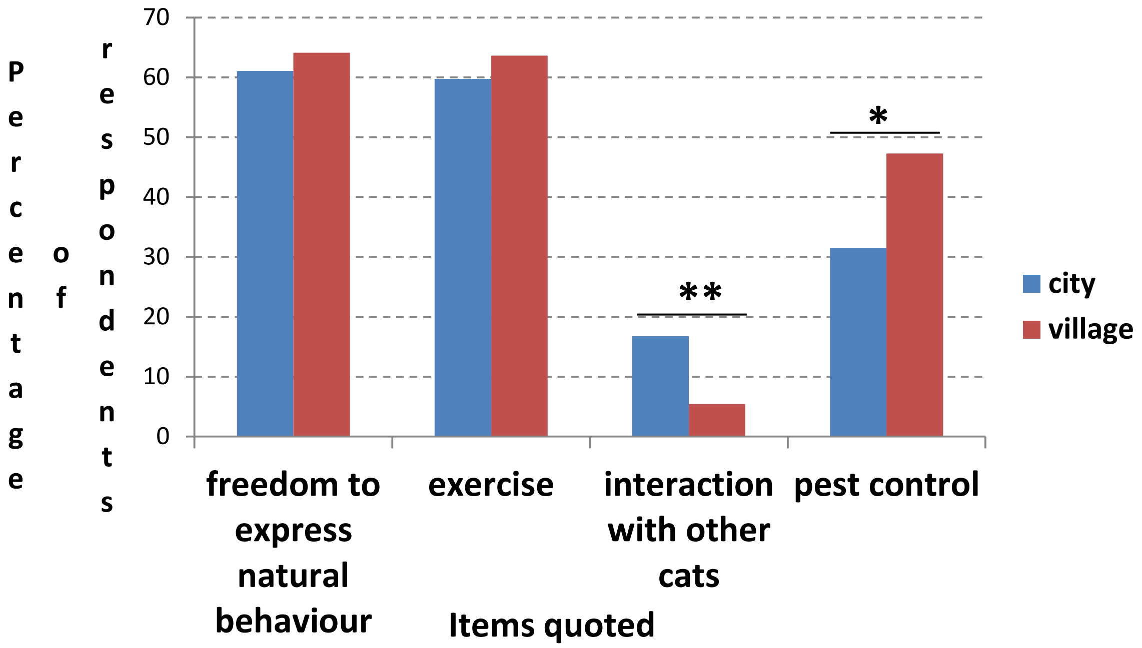

Figure 2.3: comparison of most frequently reported and significant differences in the perception of benefits for a cat to go outside and for the community, between city and village inhabitants. chi-square test df=1 . *p<0.00556; ** p<0.001.

2.3.2.2 Risks for cats to be allowed outside and problems for the community

Frequencies of answers per risk and problem and per location are presented in Table 2.4.

Risks for the cat	City (%)	Village (%)
Road traffic accident	94.6	96.8
Problematic encounters with others animals	35.8	56.9
Problematic encounters with humans	45.3	38
Disease risk	19.6	13.4
Being Poisoned	27.7	24.5
Getting lost	36.5	29.2
Being stolen	26.4	16.9
Problems cats can cause in the community	City (%)	Village (%)
Unwanted litters of cats	61.9	45.4
Disease risk to humans	16.3	6
Human being bitten by a wandering cat	2.7	1.4
Upsetting other cats	12.9	10.6
Unwanted toileting/spraying	91.8	89
Damage to property	10.9	10.1
Leaving dead/injured prey items	21.1	47.2
Others sources of neighbourhood conflicts	10.2	6.4
Killing wildlife	25.9	49.1
Cats making a lot of noise	32	18.8

Table 2.4: Frequencies of answers (%) per risk and problem and per location.

Village inhabitants quoted significantly more “problematic encounters with animals” (chi square (1) = 15.707; $p<0.0005$), “leaving of dead prey items” (chi square (1) = 25.858; $p<0.0005$) and “killing wildlife” (chi square (1) = 19.791; $p<0.0005$) than city inhabitants. City inhabitants quoted significantly more “unwanted litters of cats” (chi square (1) = 9.568; $p=0.002$) and “disease risk to humans” (chi square (1) = 10.351; $p=0.001$) as being risks for the community due to free roaming cats. There were no significant differences between city and village inhabitants regarding the risk of a cat being involved in a road traffic accident, this risk being the one most quoted in general and also by all the groups compared.

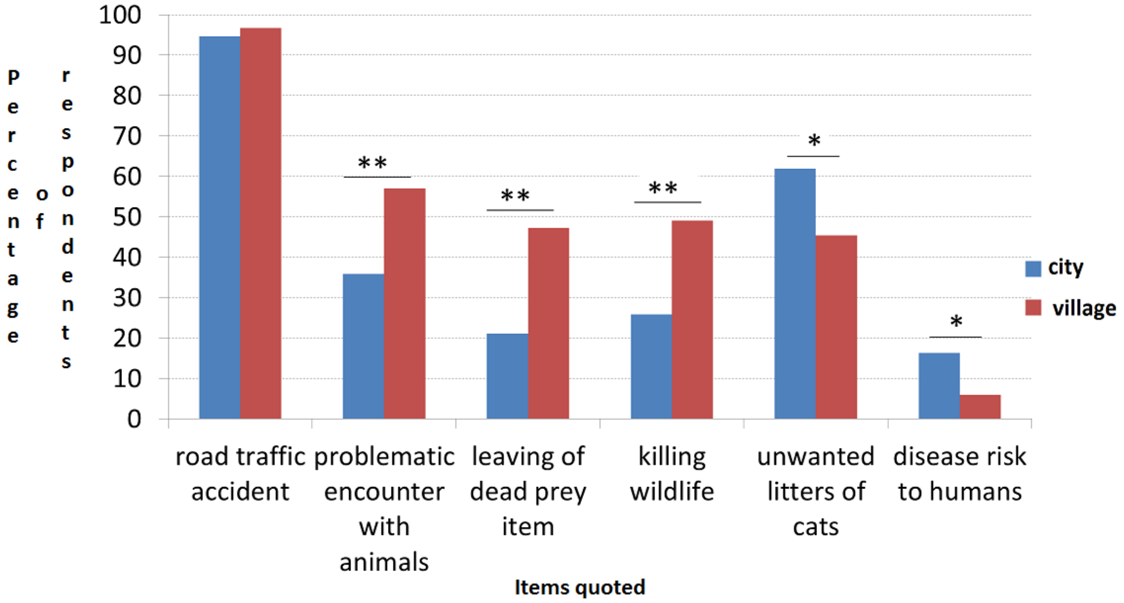

Figure 2.4: Comparison of most frequently reported and significant differences in the perception of risks and problems linked to free roaming cats, between city and village inhabitants chi-square test df=1 . *p<0.00454; ** p<0.001.

2.3.3 Cat owners versus non cat owners

2.3.3.1 Benefits for the cats to be allowed outside and for the community

Frequencies of answers per benefit and per ownership status are presented in Table 2.5.

Benefit for the cat	Owner (%)	Non Owner (%)
I think there are no benefits to a cat from being allowed	2.5	15.2
Freedom to express natural behaviour	73.9	57.6
Opportunities to hunt	14.3	14.8
Exercise	70.6	58
Interactions with humans	0.8	2.8
Interactions with other cats	5.9	12
Interactions with other animals	3.4	3.6
Interesting experiences for the cat	31.9	18
Benefit for the community	Owner (%)	Non Owner (%)
I think there are no benefits to the community from cats	7.6	14.3
Pest control	48.3	37.5
Acts as a focus for neighbourhood interaction	17.8	9.6
Provides enjoyment for those who like cats	55.9	40.6
Helps people learn about certain aspects of nature	10.2	4.4
Provides a source of routine to people's life	9.3	7.2
Gives people something special to care for	39	32.7

Table 2.5: Frequencies of answers (%) per benefit and per ownership status.

Cat owners quoted significantly more "freedom to express natural behaviour" (chi square (1) = 9.232; p=0.002), "interesting experiences for the cat" (chi square (1) = 8.977; p=0.003) and "provides enjoyment for those who like cats" (chi square (1) = 7.571; p=0.006) than non-cat owners. Non-cat owners quoted significantly more "there is no benefit for a cat to go outside" (chi square (1) = 13.123; p<0.0005) and "there is no benefit for the community of wandering cats" (chi square (1) = 18.997; p<0.0005).

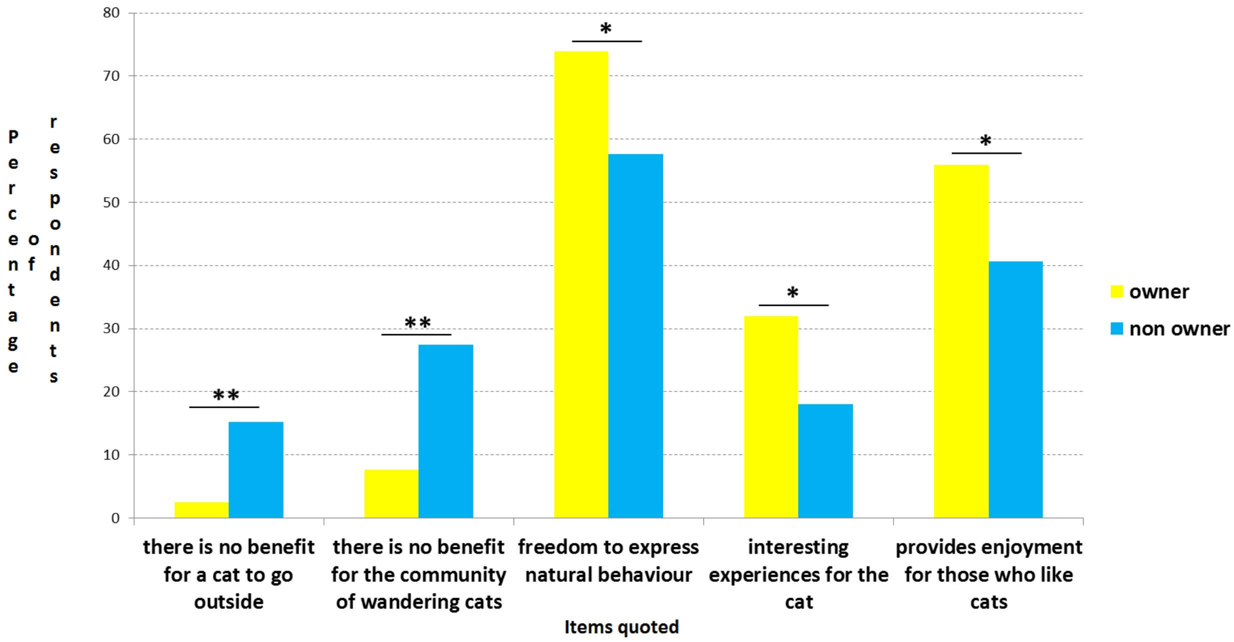

Figure 2.5: Significant differences in the perception of benefits for the cat to go outside and for the community of free roaming cats, between cat owners and non-cat owners. chi-square test df=1 . *p<0.00625; ** p<0.001.

2.3.2.2 Risks for cats to be allowed outside and problems for the community

Frequencies of answers per risk and problem and per location are presented in Table 2.6.

Risks for the cat	Owner (%)	Non Owner (%)
Road traffic accident	98.3	94.7
Problematic encounters with others animals	42.9	51
Problematic encounters with humans	46.2	38.4
Disease risk	15.1	16.3
Being Poisoned	37	20.4
Getting lost	30.3	33.1
Being stolen	24.4	19.6
Problems cats can cause in the community	Owner (%)	Non Owner (%)
Unwanted litters of cats	51.7	52.2
Disease risk to humans	8.6	14.5
Human being bitten by a wandering cat	0.9	2.4
Upsetting other cats	24.1	5.6
Unwanted toileting/spraying	87.1	91.6
Damage to property	5.2	12.9
Leaving dead/injured prey items	39.7	35.3
Others sources of neighbourhood conflicts	9.5	7.2
Killing wildlife	39.7	39.8
Cats making a lot of noise	8.6	14.5

Table 2.5: Frequencies of answers (%) per risk and problem and per ownership status.

Cat owners quoted significantly more “cat being poisoned” (chi square (1) = 11.476; $p=0.001$) and “upsetting other cats” (chi square (1) = 26.642; $p<0.0005$) than non-cat owners. Non-cat owners quoted significantly more “disease risk to humans” (chi square (1) = 16.058; $p<0.0005$) than cat owners. There were also no significant differences between cat owners and non-cat owners regarding “unwanted toileting” and “killing wildlife”.

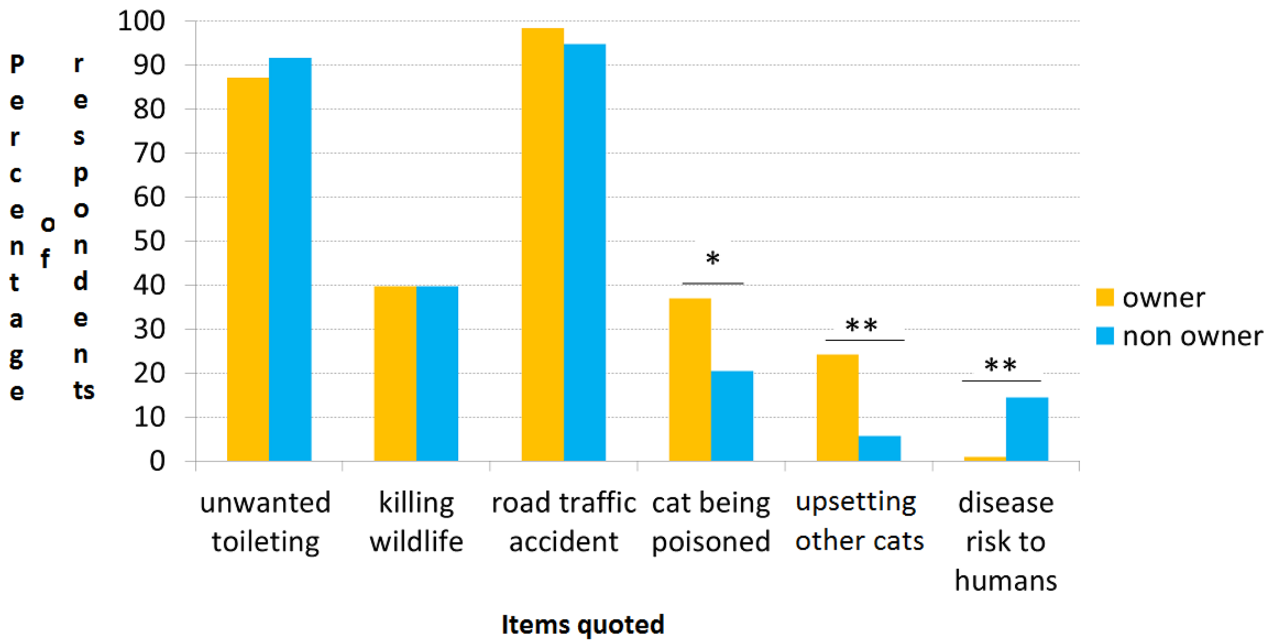

Figure 2.6: comparison of non-significant and significant differences in the perception of risks and problems linked to free roaming cats, between cat owners and non-cat owners, chi-square test df=1 . *p<0.00625; ** p<0.001.

2.4 Discussion

2.4.1 Results versus predictions

The purpose of the study was to explore people's perceptions about benefits, risks and problems linked to free roaming cats, and to see if that was influenced by whereabouts they lived (city vs. village) and whether or not they owned a cat. The overall completion rate was of 37.2%, which is within the typical completion rate for surveys focusing on cat management (Murray et al. 2009; Toribio et al. 2009; Toukhsati et al. 2007, 2012). Regarding the location status, the findings showed that village inhabitants considered pest control more as benefit, but were also more concerned about various aspects related to wildlife ("problematic encounters with animals", "killing wildlife" and "leaving of dead prey items") than city inhabitants. City inhabitants considered interactions with other cats as a benefit for cats but were more concerned about mating and disease risks ("unwanted litter of cats" and "disease risk to humans") than village inhabitants.

Regarding ownership status, in accordance with my predictions, cat owners reported more benefits for cats and for the community from cats being allowed outside ("Freedom to express natural behaviour", "interesting experiences for the cat" and "provides enjoyment for those who like cats") than non-cat owners, who significantly reported little to no benefit from cats being allowed to go outside, either for the cat or the community ("No benefit for the cat to go outside" and "no benefit for the community of wandering cats"). Focusing on risks and problems, cat owners were more concerned with cat safety and well-being ("Cat being poisoned" and "upsetting other cats") while non-cat owners were more concerned with potential impact on humans ("disease risk to humans"). However, unexpected findings were that all groups considered "road traffic accident" as one of the higher risks for cats, and that cat owners were as concerned as non-cat owners about the risk of cats "killing wildlife".

2.4.2 Cat population density

In my study the two survey areas were very distinct regarding the housing density. The same number of households occupied 5.8 ha in the city whereas it occupied 33.7 ha in the village, meaning humans and cats had more than five times less space in the city than in the village study areas. Moreover the proportion of multi-cat households was greater in the city than in the village (33.3% versus 27.02%). Despite there being a large proportion of non-responders, there is no reason to suppose that these disproportionately affected the multi-cat households in one area more than the other; therefore it is reasonable to assume that the cat population density is greater in the city area than in the rural area. My findings are consistent with those of Lepczyk et al. (2004), in which cat densities in urban areas appeared to be more than two times greater than cat densities in rural areas, and Downes et al. (2011) who found that the number of pet cat owning households was reported to be higher in city areas. This density may be one explanation for the significant differences between city and village inhabitants regarding "interaction with other cat" "unwanted litter of cats" and "disease risk to humans". Indeed, given the cat population density and also the housing structure, with terraced houses and streets in the city area and large houses surrounded by gardens in the village area, city inhabitants may well see many more cats than village inhabitants. This is confirmed in my study by answers to the question about cat sightings in the neighbourhood, where city inhabitants see significantly more cats in one week than village inhabitants. Accordingly, "interaction with other cats" would logically be a more obvious benefit for city inhabitants. However, more cats per hectare mean more possibilities of mating encounters so more possibilities of litters of cats, even if the proportion of neutered cat is high. In addition, the percentage of neutered cats being significantly lower in the city location, the possibility of more litters of cats in the city is a reality. A study on the demographic differences of two urban groups of cats (Gunther et al.

2011) showed that even in the presence of neutered cats, the group size increases because of entire cats migrating into the neutered group. Regarding disease risk, disease transmission and circulation do depend on the structure of the cat population. For example virus transmission depends on how cats are managed (Hellard et al. 2011) and also their location (rescue shelters Cave et al. 2004; Edwards et al. 2008). When the cat density is high, conflicts are also more likely because cats that are not familiar have to share the same space and avoidance strategies are more difficult to put in place. Conflict between cats is a factor in the transmission of several diseases (Feline Immunodeficiency Virus in Natoli et al. 2005 or Feline haemotropic mycoplasma Jenkins et al. 2013). Moreover, lots of parasites (including zoonotic parasites such as Toxoplasma Gondii or Giardia duodenalis) are transmitted via cat faeces (Bowman et al. 2006; Dyachenko et al. 2008; Thompson et al. 2008; Opsteegh et al. 2012) and a high cat density makes transmission more likely. Therefore this ‘reality’ (i.e. greater potential disease risk) might be reflected in the greater concern of urban people about impact of cats on humans (urban people were significantly more concerned about “disease risk to humans”).

2.4.3 Wildlife abundance in the countryside (around the village location)

The two study areas were also very distinct regarding the landscape. In the village area the households were surrounded by large gardens and separated by hedges, providing lots of vegetation to explore, whereas in the city area most of the landscape comprised houses, streets, and patches of green spaces with trees located more on the edge of the study area. The study area was in the heart of the city and surrounded by a high density housing environment rather than the countryside, unlike the village area. Increased housing density and urbanisation are linked with decreased wildlife abundance (Stout et al. 2006; Evans et al. 2009) even if some species of birds and mammals try to adapt to the change in landscape (Burhans and Thompson 2006; Sarno et al. 2014). The abundance of wildlife in the village location may account for the village inhabitants seeing more “pest control” as a benefit and being more concerned about wildlife related issues such as “killing wildlife”, “leaving dead prey items” but also “problematic encounters with animals”, compared to city inhabitants because they are more accustomed to the presence of other non-human, non-cat animal species.

2.4.4 Caring for cats and for their wellbeing

Regarding cat safety, cat owners are more generally concerned for their cat safety than non-cat owners (Toukhsati et al. 2012). This is consistent with my findings. It could also account for the very clear difference found between cat owners and non-cat owners regarding the benefits from being allowed outside. In my study, cat owners cited significantly more the importance of "Freedom to express natural behaviour", "interesting experiences for the cat", and "provides enjoyment for those who like cats" compared to non-cat owners. By contrast, non- cat owners stated significantly more that there was "No benefit for the cat to go outside" and "no benefit for the community of wandering cats". This supports the findings of a previous study on attitudes towards cat containment in Australia (Toukhsati et al. 2012) where non-cat owners were more in support of total containment indoors and their primary reasons were linked to the potential impact of cats on wildlife (which may be related to the fact that cats are a serious threat to wildlife in islands such as New Zealand and Australia (Keedwell 2005; Recio et al. 2010) , whereas cat owners supported part time containment first in order to keep their cat safe.

2.4.5 Frequently reported items in risks and problems

There were no significant differences between owners and non-owners regarding the items of "unwanted toileting" and "killing wildlife", which were frequently reported (above 87% for "unwanted toileting" and 39% for "killing wildlife"). This shows that cat owners are themselves aware that their cats can cause problems within the community and that they perceive the unwanted toileting and also the potential killing of wildlife as problems. These findings are consistent with those of Thoukhsati et al. (2012), mentioned above who found that cat owners were as concerned as non-cat owners about the potential impact of cats on wildlife, which is perhaps contrary to the popular stereotype of the cat owner who does not care about this issue. Given that cat owners are aware of the problems cats can cause, they might be more receptive than may have been previously assumed to a change in management policies, providing that the cat's welfare is respected. Finally, all groups surveyed (cat owners, non-cat owners, city and village inhabitants) frequently cited "road traffic accident" as one of the main risks to cats being allowed to go outside and there was no significant difference between cat owners and non-cat owners, or city and village inhabitants on this point. Although for cat owners this concern for the cat safety may seem obvious, it may be that for non-cat owners the concern is related more to the risk and distress posed to humans from an accident, but even so this is perceived as a common enough event to be a major concern for all parties.

2.4.5 Potential confounding factors

In order to increase the response rate, the questionnaire had to be kept very short. I chose to keep the demographics questions about the respondents to a minimum in order to avoid extending the questionnaire's length and deterring people from responding. Therefore I had no information about the socio-economic status or age of the respondents, both factors being known to influence answers about questionnaires (Perkins-Porras et al. 2006; McDonald et al. 2015). Since housing density may be linked to socio-economic factor, the differences found between the city and village inhabitants might have been influenced by the socio-economic background and age of the respondents. In my study, city inhabitants of the surveyed zone were very variable: some of them having difficulty speaking English while others were fluent and long established in the area. Students were also more common in the city sample. The village inhabitants were, for the most part, long established residents in the village and might be expected to have a higher income than the city inhabitants that were surveyed. To explore further the potential socio-economic influence on people's perception, one addition to the experiment would be to get more demographic and socio-economic information and to take it into account in the analysis of the data, comparing socio-economic categories rather than type of housing. One other possible experiment would be to match the type of housing (as they are zones in the city with large houses and gardens) and survey the two zones simultaneously to be able to compare those results with my current results.

2.5 Conclusion

People's perception about the benefits, risks and problems linked to free roaming cats are diverse and influenced both by where they live and whether or not they own a cat. However, common ground can be found in the problems thought to impact upon the community caused by cats, such as toileting outside the boundaries of their owner's property and the potential impact of cats on wildlife. Furthermore, all groups considered that road traffic accidents are a high risk for owned cats with access to outdoors.

In the next two chapters we will examine this topic further by moving away from the human perception of cat behaviour and risk, instead focusing on what cats themselves actually do when they are allowed outside that may or may not put them at such perceived risk.

Chapter Three

Development of a Global Position Satellite (GPS) tracking device for free roaming domestic cats

3.1 Introduction

Domestic cats are spread worldwide and their number makes them the second favourite pet after the dog. Their breeding success can have unwanted consequences, such as the presence of feral uncontrolled populations of cats which, associated to owned free roaming cats, may have a negative impact on wildlife or become a neighbourhood nuisance (McLeod et al. 2015). In parallel, interests in the cat as a pet, as well as concerns for free roaming owned cats safety has arisen. Therefore finding a reliable way to track domestic cats, whether they are feral or owned, became essential. In the last decade, advances in technology have allowed researchers to monitor animal movement through Global Position Satellite (GPS) monitoring devices. Advances in miniaturisation have resulted in the production of lightweight GPS devices suited to track small to medium sized animals (Recio et al. 2011) and at least 10 published studies have used GPS to track domestic cats (see Table 3.1). GPS devices have been used to study the impact of feral cats on wildlife and biodiversity (Martin et al. 2013; Hervias et al. 2014) and to evaluate cat control programs (Moseby et al. 2009; Bengsen et al. 2012). Most of these studies were carried out on feral and semi-owned cats (Recio and Seddon 2013; McGregor et al. 2014) [where semi-ownership is defined by the provision of food and shelter to a cat by a person that does not consider himself the owner of this cat] with the exception of two studies; one following owned and semi-owned cats (Hervias et al. 2014) and one exclusively following owned cats to quantify their movement patterns in an urban environment (Thomas et al. 2014). In connection with concerns for free roaming cat safety specifically across roads, in this study I sought to understand better the roaming behaviour of domestic owned cats, a population that has been little studied, in order to determine what factors could influence said roaming behaviour, such as the housing density and spatial distribution of households. To that effect I needed a programmable and custom GPS device, which functioning parameters (e.g. accuracy) I sought to determine.

Authors Year of publication	Title	GPS used	Feral/Owned/Semi-Owned cat (F/O/SO)	Number of cats
Moseby et al. 2009	Movement patterns of feral predators in an arid environment – implications for control through poison baiting	GPS collar **135g** SIRTRACK	F	13
Recio et al. 2010	First results of feral cats (*Felis catus*) monitored with GPS collars in New Zealand	GPS data-logger collar Total weight for each collar was **125 g**.	F	5
Bengsen et al. 2012	Applying home-range and landscape-use data to design effective feral-cat control programs	GPS logger collars collar release mechanism **137g to 154g**	F	13
Martin et al. 2013	Movements and space use of feral cats in Kerguelen archipelago: a pilot study with GPS data	GPS data loggers. The equipment weighed **165 g** in total.	F	3
Recio and Seddon 2013	Understanding determinants of home range behaviour of feral cats as introduced apex predators in insular ecosystems: a spatial approach	GPS data logger collar (Sirtrack, Total weight of the collar was **125 g**	F	21
Cruz et al. 2014	Seasonal and individual variation in selection by feral cats for areas with widespread primary prey and localised	GC 128 model, **135 g**, www.sirtrack.com,	F	17
Hervias et al. 2014	Assessing the impact of introduced cats on island biodiversity by combining dietary and movement analysis	GPS logger (4.4 × 2.7 ×1.3 cm of size,) Weight on website **20 g**	O+SO	21
McGregor et al 2014	Landscape Management of Fire and Grazing Regimes Alters the Fine-Scale Habitat Utilisation by Feral Cats	GPS collars 70 g collar, 100 g collar	F	32
Thomas et al 2014	Ranging characteristics of the domestic cat (Felis catus) in an urban environment	CatTrack™ GPS units weighed **22 g**(4.4×2.7×1.3 cm)	O	20
Kitts-Morgan et al 2015	Free-Ranging Farm Cats: Home Range Size and Predation on a Livestock Unit In Northwest Georgia	CatTraQ GPS units (44 x 27 x 18 mm) **22g**	SO	7

Table 3.1: Publications using lightweight GPS devices to study the movement patterns and home range of domestic cats.

One very important parameter in studies using GPS mounted device studies is their weight.: firstly, from a welfare point of view, the cat must be comfortable wearing the device and its mobility and energy expenditure should not be compromised by additional weight. Furthermore, from an experimental point of view, if the size and/or weight of the device affects the cat's behaviour and movement, this may lead to false conclusions regarding home range and habitat use. For example, an individual with an oversized GPS device may travel less distance than normal due to the additional costs associated with travel following tagging. In the ten studies referenced in Table 3.1, the weights range from 20-22g for GPS unit alone (not taking into account the weight of the collar or the harness on the cat, Kitts-Morgan et al. 2015; Hervias et al. 2014) to 165g for the total equipment (device plus harness, Martin et al 2013). In most studies researchers did follow "the rule of thumb" (Coughlin and Van Heezik 2015) stating the weight should not represent more than 5% of the body weight of the cat, but more recently it has been suggested that the weight of a collar mounted device should not exceed 2% of the body weight (Coughlin and Van Heezik 2015), which means that for the average cat (3 to 4 kg) the equipment should not weigh more than 60 to 80g.

Other important parameters about the GPS device are the number of fixes per period of time, the device accuracy (ie the device being able to pinpoint the cat's location as accurately as possible) when the cat is mobile, and the positional error when the device is not mobile, for example when the cat sleeps.

The numbers of fixes per period of time can be adjusted on most GPS devices and the chosen setting is generally determined by the particular requirements of the research question. For example, in studies of habitat use and the diet of feral cats (Recio et al. 2010; Recio and Seddon 2013; McGregor et al. 2014), the length of time between fixes was programmed to be minutes or even hours in order to gather data over long time periods and minimise the demand on batteries without compromising the ability to detect the features of interest, since the cycle of capture/recapture has to be kept to a minimum. However, if this frequency of sampling is adequate to determine a home range provided that the duration of sampling is sufficient, data will often be scarce regarding cat movements and such infrequent sampling would not be suitable in other circumstances. For example, in order to track owned cats in a complex environment, the period of time between fixes should be low, e.g. the GPS device would be programmed to record the cat's position every second to provide precise records of movement within diverse environments.

The device accuracy is a primary parameter: for example, when the device's accuracy is two metres, it means that for each data point, the actual cat's location is comprised in a circle of two metres' radius centred on the data point. The accuracy of the device is determined first through the accuracy of the receiver, i.e. the accuracy of the microchip embedded in the device. The HDOP (Horizontal Dilution of Precision) relates to the geometric arrangement of satellites to calculate a location (Bengsen et al. 2012: Recio and Seddon 2013). These parameters, along with the number of satellites logged on the device at any moment, are keys to the GPS device accuracy. In the 10 studies referenced in Table 3.1, it might be possible to infer the accuracy of the system from information provided by the supplier (Moseby et al. 2009; Recio et al. 2010; Kitts-Morgan et al. 2015) or the strategy used by the authors, e.g. to remove all locations with an HDOP>9 (Recio et al. 2010; Bengsen et al. 2012; Recio and Seddon 2013) or HDOP>10 (Cruz et al. 2014). The supplier may only provide the receiver accuracy (Kitts-Morgan et al. 2015) which is inadequate to determine the accuracy of the device in working conditions, as it merely states the best accuracy in optimal conditions. Sometimes no mention is made of the accuracy at all (Martin et al. 2013). But even with the parameters provided by the manufacturer and the HDOP known, different types of environment (e.g. grass, trees, urban environment) can remain a problem, with the type of cover influencing communication between the device and the satellite. The best way to assess the actual accuracy of a device is to test this accuracy in the field, i.e. either put some motionless devices in the study area (Bengsen et al. 2012; Recio et al. 2013, Thomas et al. 2014); and/or to put some devices on animals and then track their exact location by another means, for example by observing visually the location of the cat or using a VHF radio-tracking, and compare the GPS readings and the real observed locations. This latter solution may not be possible in the case of feral cats or other cats that are free to roam and therefore far more difficult to keep in sight when directly tracking, but is certainly possible for owned cats. Thus, in order to develop a GPS tracking device I decided to use this solution, which provides greater information on the accuracy of the device (i.e. accuracy of the receiver plus HDOP).

Finally, the last parameter to take into account is the positional error, which is very different from the device accuracy. For example, if a device is accurate at two metres, it means that if the cat is at position X, the location pinpointed by the device is actually a two metres circle, with the position X somewhere inside the circle. This is true when the cat is mobile. But when the cat is not mobile for a long enough time for the device to pinpoint the location repetitively, the positional error may appear, i.e. the locations pinpointed by the device will not be the same, so the cat will appear to be moving when in reality it is not moving. This positional error is due to the fact that in order to pinpoint the subject's position, satellites are geometrically arranged and communicate together. This arrangement may have to be adjusted due to the Earth's rotation, and even a tiny adjustment can lead to a positional error of several metres. To tackle this problem, one possibility is to program the device to log its position at large intervals of time if it is consistent with the research question investigated (for example every few hours; Bengsen et al. 2012). This way, the subject is less likely to have moved when the device pinpoint its location. If the research question does not allow it, it is possible to gather information about the positional error using a motionless unit to record the position (Hervias et al. 2014). This is a good idea in principle, however, the motionless unit would not be in the same environment as the subject, and the environment might influence the positional error (for example a deep tree cover which would not allow the device and the satellites to communicate perfectly.) Another way that allows the researcher to tackle positional error is to use an animal movement model (ie a model that represents the biological movements of the animal studied) and to remove all locations that are compatible with the normal biological movement of an animal (Recio and Seddon 2013). Following this idea, only biologically relevant positions are kept in the analysis, but it implies a detailed understanding of the species studied and their maximum speed. Some leeway also has to be given to individual variation, in order not to exclude positions that are real. Finally, adding an accelerometer would allow differentiating between the logs pinpointed when the cat is really moving and when it is not, but the data from GPS and accelerometer have to be linked and the accelerometer may add weight to the equipment, which may be an issue (see discussion on weight earlier in the chapter).

3.2 Methods

3.2.1 GPS device

I used a custom built GPS device built by Dr John Murray of the School of Computer Science at the University of Lincoln with a 500x Life Cycle Lithium Polymer Battery, Autonomous Global Positioning System sensor, 4GB MicroSD card and MicroSD card writer. A tri-axial accelerometer was also included in order to determine when the cat was mobile or not. The device measured 25mm in diameter and 34mm in length and was mounted on a standard cat elastic collar, secured with tape. The total weight of the equipment (device plus collar) was 25g. The GPS sensor was set to record a set of parameters (i.e. the device location, the number of satellites logged on to the device – "fixes" and the time of location) every second.

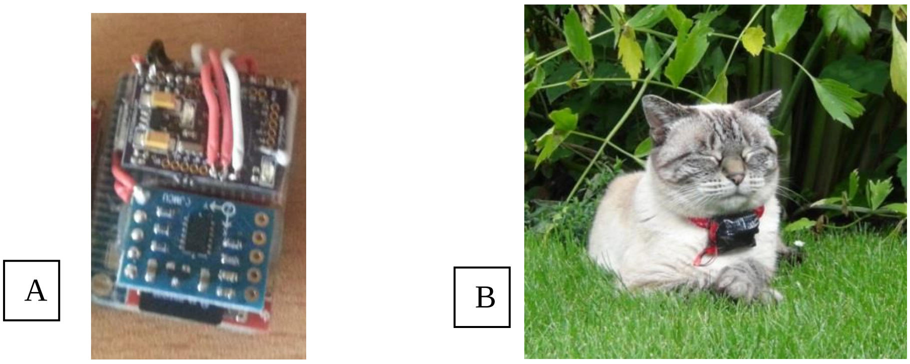

Figure 3.1: **A** Picture of the device **B** Cat wearing a device mounted on a collar.

3.2.2 Determining device accuracy and battery life

In order to examine the operational characteristics and accuracy of the device, an initial study was conducted on five cats at the University of Lincoln. The cats were three males and two females, all neutered, with ages ranging from 2 to 8 years old. The study took place in an outdoor enclosure attached to the Cat Welfare Centre of the University of Lincoln's Riseholme Campus. This area measured 8.5m by 8.8m, with a height at 2.4m, with wire mesh for walls and roof. It was divided into three areas, one area with an earth floor, one area of shrubbery and one wooden deck with wooden shelves where the cats could perch (Figure 3.2).

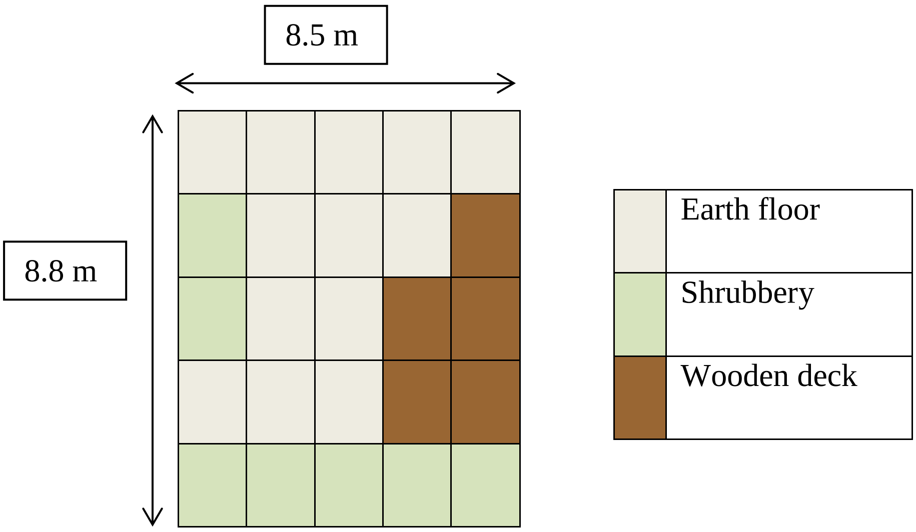

Figure 3.2: Schematic representation of the external enclosure of the cat welfare centre.

3.2.2.1 Conditioning to accept the device plus collar

The five cats had been habituated to the area by being given access every day for at least one hour during two weeks prior to the study. They had also been conditioned to wearing a collar without the GPS device (taking into account their previous experience) by associating the collar with treats. The collar conditioning lasted three to five days depending on the cat. Then the cat was fitted with the collar with device, for 10 minutes, repeated several times until the cat showed no signs of discomfort (e.g. Scratching the collar) and performed typical pre-collar behaviours without attending to the collar. Then the validation process began.

3.2.2.2 Study protocol

The same protocol was applied for each session. A Sony HDR-XR260 handycam was used for all filming. Firstly, the device was turned on by plugging the battery into the battery case and placed horizontally on the floor for three minutes (for the GPS to acquire a satellite fix, i.e. connect to the satellite). Then the experimenter began filming the device for 15 seconds, then held the device vertically for a few seconds and then placed it back horizontally for 30 seconds while filming in order to have a point of reference that enabled alignment of the video footage. After this step, the device was fitted on to the designated cat and the cat released in the outdoor enclosure. The cat was filmed for 45 minutes; 30 minutes with limited interaction with the experimenter followed by 15 minutes when the experimenter interacted with the cat, encouraging it to perform a variety of behaviours including: play, sitting, standing, crouching, walking, trotting and jumping. This specific part of the session (The last 15 minutes) was performed in order to ensure a minimal number of behaviours were performed by the cat at each session to test the collar in every possible condition and ensure that the cat was able to perform its behavioural repertoire without any discomfort. After this period of observation, the experimenter took the collar off the cat, unplugged the battery and left the cat free in the outdoor enclosure for around 10 minutes. Then the cat was returned to its indoor personal pen. Each cat completed five of these 45 minute sessions.

3.2.2.3 Device accuracy

In order to assess the effect of the number of satellites registered by the GPS device on the accuracy of the GPS data, one session per cat was chosen randomly. For each session 20 points were selected, and the data point chosen were distributed equally for each number of satellite tested (i.e. if we had 30 minutes with 9 satellites, and the sampling frequency is every second, 30 minutes are converted in 1800 seconds. In order to select 20 equidistant points, I took one point each 90 s). The satellite fixes compared were seven, eight, nine and 10. Each individual data point was plotted on to Bing Maps and using the corresponding video footage, the cat's actual location was also plotted. The distance between the GPS location and actual location was measured by the mapping software. This allowed us to generate a value for the 'error' between the GPS and real data.

3.2.2.4 Positional error

In order to determine the positional error, I used two methods. First I used a motionless device for several hours, placed inside a house near on the windowsill (66 cm in height), and then at a cat's level outside under cover or outside with no cover (Thomas et al 2014).

3.2.2.5 Accelerometer data

The accelerometer data were downloaded into an Excel sheet and the data were plotted on graphs. Points in the videos where the cat was not mobile (preferably for more than one minute) were matched on the corresponding Excel sheet.

3.3 Results

3.3.1 Satellites vs. device accuracy and battery life

I collected approximately 61000 fixes, with the fixes success rate being more than 90% (i.e. the device was able to get a fix every second for more than 90% of the time). The number of satellites logged on each fix varied from 5 to 12. As expected, the accuracy of the cat's location depended on the number of satellites logged on the device and was 6.69 m +/-3.04 metre (mean +/-sd) with 10 or more satellites and 13.41m +/-6.15 metre with seven satellites (see Figure 3.3). When the device was programmed to get a fix every second, the battery was found to be sufficient to provide data for up to six hours per day if recharged daily; with the overall battery life lasting two to three weeks.

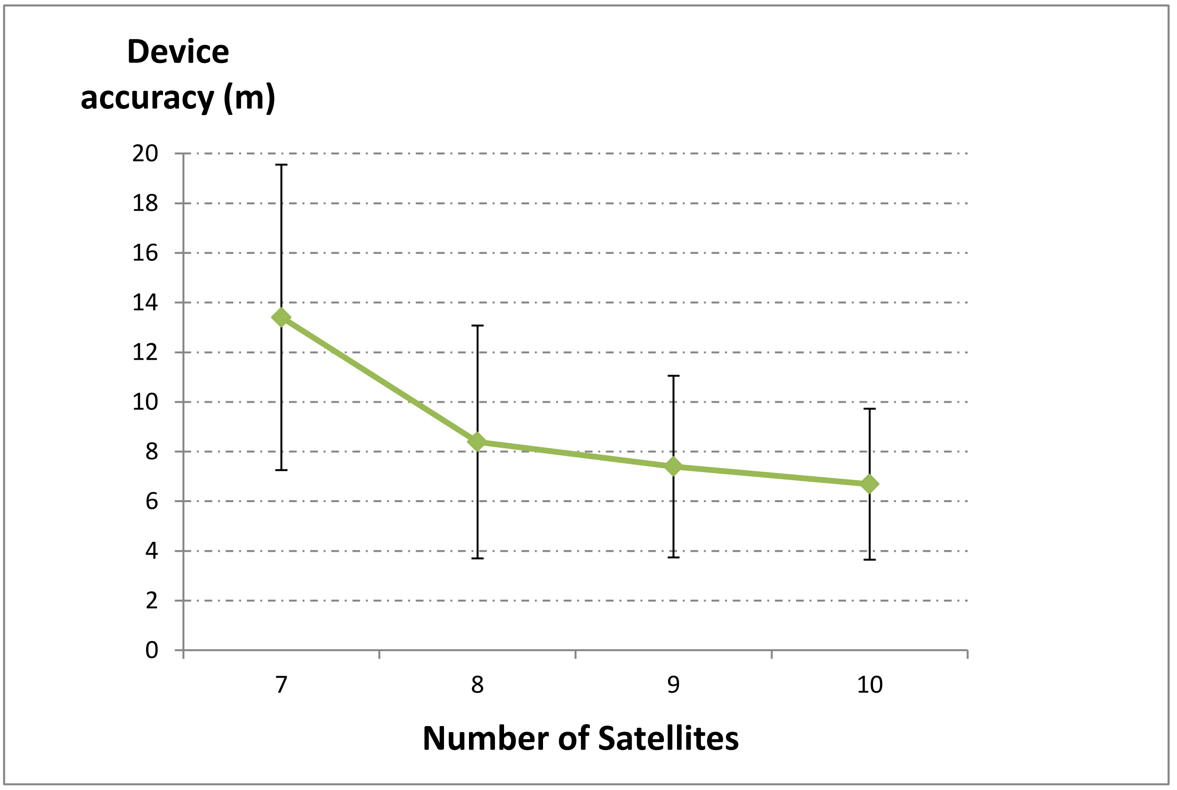

Figure 3.3: Device accuracy in metres (mean ± SD) depending on the number of satellites.

3.3.2 Positional error

With the motionless device, the positional error was variable over time, ranging from one metre to 15 metre when assessing all the conditions (in the house, in the garden under cover, in the garden in the open). The positional error seemed to be a bit smaller when the device was in the garden in the open, but I got at least three errors of 15 metres even with no cover.

3.3.3 Accelerometer data

I determined that when at least two of the three axes of the accelerometer (x,y,z) showed a change of more than 30° in angle, the cat was mobile. In every other case the cat was not mobile (see Figure 3.4).

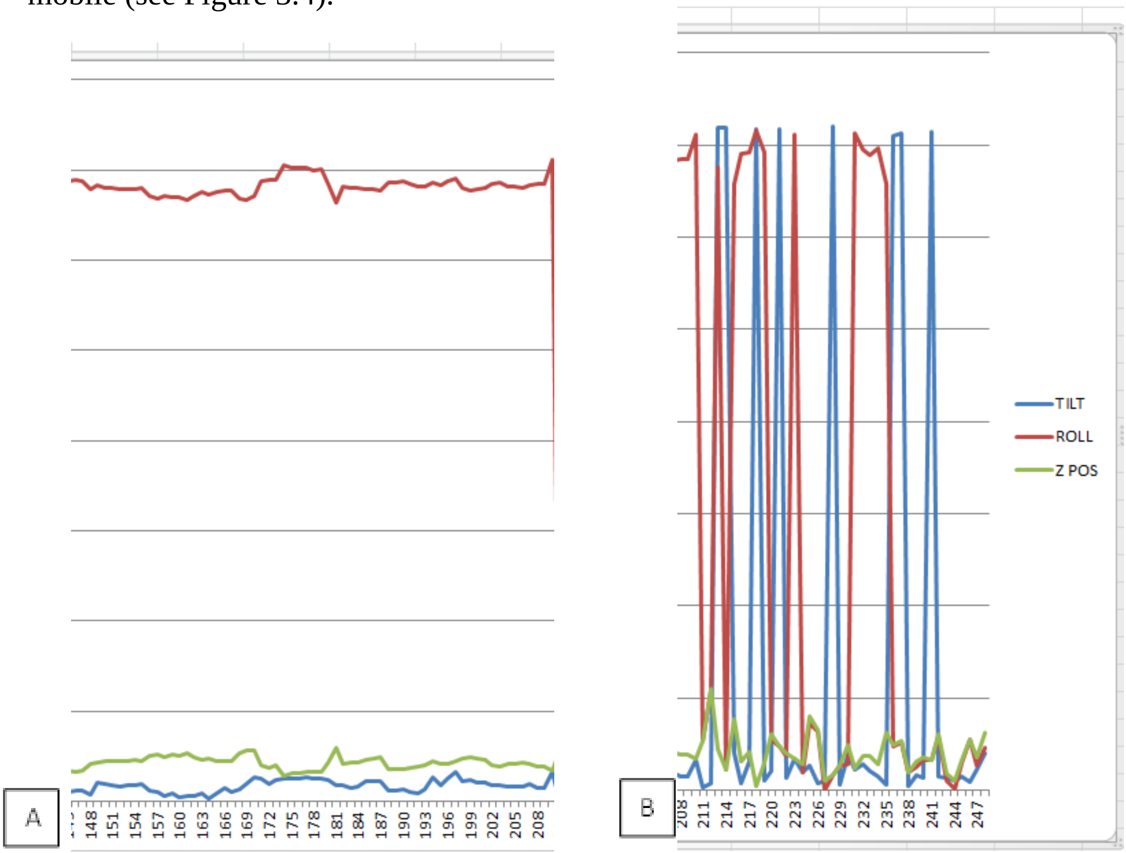

Figure 3.4: Example of accelerometer data **A** Cat not mobile **B** Cat mobile

3.4 Discussion

In line with previous studies using GPS to track domestic cats, I found that the number of satellites logged on to the device strongly affects the accuracy of the data on the cat's position (Recio et al. 2010; Van Heezik et al. 2010; Bengsen et al. 2012). I found that seven satellites logged on to the device was the minimum number to achieve an accuracy that was below 15 metres; above 10 satellites and the accuracy was within 6 metres. This accuracy is well within the range of accuracy by previous studies (from six metres in Thomas al. 2014 to 50 m Recio et al. 2010). This accuracy allows more intensive and precise tracking of the animal's movement. In other studies, accuracy is usually mentioned in the methods but rarely discussed; it is assumed to be sufficient to answer the research question.

In fully rural environments, vegetation and topography are known to influence the location error in GPS (D'Eon et al. 2002; Recio et al. 2011), probably because they influence the number of satellites that can be logged by the device, alongside the animal's movement (i.e. the collar moving around together with the animal's movement also impacts the ability to acquire a satellite fix). The Cat Welfare Centre at the University of Lincoln had no nearby tree cover or tall structures which may account for the high number of satellites logged per fix. Achieving good quality satellite coverage (i.e. from the results, achieving an accuracy below 15 metres when the cat is mobile means at least 7 satellites logged on to the device) could be more difficult in a city environment, particularly where there is a high concentration of tall buildings and may lead to less data being available to analyse. The GPS device was set to record location every second, which is a more intensive tracking protocol than used in previous studies where the device acquired fixes from every 15 min to every 5 hours (Recio et al. 2010; Van Heezik et al. 2010; Bengsen et al. 2012). While this could help to mitigate against the loss of data from inadequate satellite coverage; which is necessary when interested in detailed behaviours such as road crossings, this intensive rate of fix acquisition had a negative impact on battery life. Accordingly, batteries needed to be charged every six hours, which compares with 3 to 18 days (Recio et al. 2010) and 20 to 206 days (Bengsen et al. 2012) of other studies. There is therefore a clear trade-off between battery life and the intensity of tracking (Recio et al. 2010; Tomkiewicz et al. 2010), which needs to be considered according to the research question being addressed. For example, when trying to define and compare home ranges over a relatively short time scale (as in the following experimental study, see Chapter 4) and studying road crossing that can be performed in seconds by cats, frequent sampling is preferable since it provides the necessary precision, whereas less frequent sample may be adequate when more generally monitoring the presence of cats in a given area e.g.(Recio et al. 2010; Bengsen et al 2012; McGregor et al. 2014). A possible way to improve battery life would be to have a device that can switch the GPS recording off when the cat is not mobile. GPS systems currently exist that "switch off" the program if the device cannot find a fix (Recio et al. 2010); however, additional hardware to monitor and respond to inactivity may increase the overall weight of the device (in Recio et al. the device plus collar weighs 125 g) which may not be advisable when measuring movement (Coughlin and Van Heezik 2015).

3.5 Conclusion

I developed a GPS tracking device in order to monitor cat movement that has good positional accuracy and a positional error that falls well within the range of previous research; and with a weight that ensures that this will not be a factor of influence on the cat's behaviour. The battery life is short compared to other studies due to the necessary frequency of fixes, but the device and its collar are made in order to be worn only when the owned cat is outside and to be taken off the cat (for recharging of batteries, but also because data is not required) when the cat is inside the house. Having now established that the technology is appropriate for answering my particular research questions, in the next chapter I go on to use the GPS device in order to track the movement of cats in a complex urban environment and consider how the cat's behaviour reflects the opinions of people living in the same community.

Chapter Four

Use of Global Position Satellite (GPS) to track domestic cats in urban environments

4.1 Introduction

Many owned domestic cats are allowed access to the outdoors either on a permanent or restricted basis. Whilst the majority of cat owners consider greater freedom for their cats to express natural behaviour as a benefit of outdoor access (Jongman 2007; Chapter 2), roaming also creates a number of potential risks for cats, the human population and wildlife (Baker et al. 2010; Gehrt et al. 2013). These include risks of injury to the cats through accidents (Rochlitz 2003a, b), poisoning, aggressive interactions and infection (Lloyd et al. 2013). Cats may also cause problems for the community they are living in such as unwanted toileting on people's properties and risks to human health (Chomel et al. 2006; Afonso et al. 2008), unwanted litters, and finally predation of wildlife (Lilith et al. 2006; Baker et al. 2008). Some of these risks can be reduced by responsible owner behaviour (Murray et al. 2009; Finkler and Terkel 2012): such as neutering to reduce risk of unwanted litters, aggressive cat-to-cat interactions and subsequent infections; vaccination, worming and flea control reduces disease spread; controlled management of a cat's outdoor access can reduce risks to wildlife and the risk of the cat being involved in road traffic accidents (Rochlitz 2003b). However, the specific factors affecting these risks associated with the roaming behaviour of owned cats (see Liberg et al. 2000 for review; Horn et al. 2011; Gehrt et al. 2013) remain largely unknown, and so it is not surprising that the perceived value of the costs versus benefits of outdoor living is a matter of some controversy; the appropriateness of legislation being debated in a number of countries (Lilith et al. 2006, 2008; Toukhsati et al. 2012).

It is already known that there is considerable variation in the area covered by cats with a large number of factors thought to influence roaming behaviour, such as the local provision of food and the density and make up of local cat populations (Barratt 1997). Physical barriers, such as fences or rivers, or psychological barriers, such as areas to be avoided like busy roads; high human or cat population densities, may also influence the movements of cats. This may in part explain why urban cats have been found to roam less than those living in more rural environments (Barratt 1997). In addition, age, prior experience, gender, environment, ownership (i.e. owned vs. unowned/feral) and neuter status can affect the size of territories as well as roaming behaviour outside of territorial boundaries (Baker et al. 2010). For example, unowned cats tend to range further than owned cats as they make use of multiple or less predictable food sources (Biro et al. 2003;

Horn et al. 2011), and entire male cats roam further than other genders when seeking mates (Say and Pontier 2004).

One restriction to the gathering of accurate information on the roaming behaviour of cats is the data collection technique. Direct or video observation only gives a snapshot of visits to specific areas. Tracking of cats using VHF radio transmitters has been widely used (e.g. Barratt et al. 1997; Biro et al. 2003; Molsher et al. 2005; Lilith et al. 2008; Wierzbowska et al. 2012; Gehrt et al. 2013), although this approach faces a number of logistical issues. These include the need for the subject to be within range of the tracker, the manpower required to track multiple individuals at the same time and the associated financial costs. Such constraints may limit the number of animals tracked and/or the length of time that individuals are surveyed (Recio et al. 2011). By contrast, the use of Global Position Satellite (GPS) technology offers an alternative approach for tracking individual animals in real time (Tomkiewicz et al. 2010; Swain et al. 2011; Costa et al. 2012) and has been used successfully to identify the location and movement of animals in diverse contexts, such as the grazing locations of hill sheep (Rutter et al. 1997), the flight paths of homing pigeons (Meade et al. 2005) and calving behaviour of red deer (Asher et al 2014). The rapid evolution of the technology, including greater satellite coverage to support more accurate measurement, and reductions in size and weight of GPS data loggers and their power supplies (Recio et al. 2011), has significantly increased the potential to use these devices to track smaller animals, whilst minimising interference to their movement.

All resident animals restrict their movements to fairly well-defined areas, a concept known as a home range (Powell 2012). There are a number of methods used for estimating home range size (see reviews by Harris et al. 1990; Laver and Kelly 2008; Kie et al. 2010), but there is no such thing as a “best method” for home range estimation (Fieberg and Börger 2012). Instead, the most appropriate estimator is dependent on the research questions being addressed as well as the type and nature of the data (Fieberg and Börger 2012). So far, GPS tracking studies of owned and feral cats typically report a variety of approaches used to estimate home ranges, including minimum convex polygons (MCPs), harmonic means contour (HM), kernel density estimates (KE; e.g. Van Heezik et al. 2010 ; Bengsen et al. 2012; Hervías et al. 2014) and adaptive local convex hulls (a-LoCoH; Bengsen et al. 2012). Technical details of these methods are provided later, but clearly the choice of home range estimator is important both in the context of understanding space use by cats, as well as cross-study comparisons.

Some estimators, for example MCPs, can over-estimate home range sizes depending on the shape of the range (White and Garrott 1990), while the Harmonic means can display sharp peaks or over-smooth contours, depending on the underlying grid used (Powell 2000). For owned cats or individuals in environments featuring many potential physical and psychological barriers, it is therefore unclear the degree to which estimators accurately estimate home range size. A small number of GPS studies have been conducted on cat populations in Australia and New Zealand, using the 100% Minimum Convex Polygon (MCP) and 95% Kernel Estimator (KE), or Local Convex Hull (Lo-Co-H) (Recio et al. 2010; Van Heezik et al. 2010; Bengsen et al. 2012). The 100% MCP has the longest history of use and is typically used to compare studies, but as mentioned above, may greatly over-estimate the size of the home range. Instead, the 95% KE is often found to be a more reliable estimator of home range size but is sensitive to the density of points. The Harmonic mean method has not been used in these recent studies of cats. Studies have also mentioned that accuracy of the cat's recorded location depends on the number of satellites logged on the GPS collar (Bengsen et al. 2012) and that it increases as the number of satellites becomes higher, but without linking the number of satellites to a precise level of accuracy.

Given the relatively limited use of GPS in owned cats in urban situations, I sought to undertake a study to investigate home ranges in owned cats, in order to better understand what factors may influence their home range and if cats living in two different urban environments may have different home ranges. In connection with concerns for cat safety coming from the estimation of cat deaths on the road (nearly 230 000 every year according to PetPlan in 2006), the second purpose of the study was to evaluate road crossing in owned cats around their homes. In the previous study (Chapter 2), people perceived the risk of a cat being involved in a road traffic accident as a very high risk. By studying the road crossing behaviour of cats in the same zones of the previous study, I sought to compare people's perceptions to the reality their cats are living in.

I compared different methods to determine the weekly home range asymptote and core area of two groups of owned cats living in one of the two urban environments previously surveyed (Chapter 2), either a city or a rural setting. These represent complex but comparable environments with a high degree of potential cover but different patterns of resource distribution. I assumed that the rural-based urban cats (RU cats) and city-based urban cats (CU cats) would have differently sized and shaped weekly home ranges, as a result of differences in the space available to explore, the density of cats and the pattern of distribution of resources (See Barratt 1997). Therefore I was interested in the power of the different methods to potentially detect this difference, and the direction of the difference according to method chosen. For focally distributed resources (such as might occur in an city urban setting where there are more no-go areas), relatively crude methods of estimation such as MCP are likely to grossly over-estimate total home range size in general, but also locally according to the pattern of distribution of these resources (e.g. a higher density of small areas may have a larger total area than a smaller number of larger more widely distributed areas). The effect of this error on these methods can be expected to be greatest when a higher proportion of the data are used as rarely visited peripheral locations are more likely to be included. However, differences in core area could be small if, for owned cats, most essential resources are concentrated within the owner's home. Therefore, in this instance I was interested in the level of convergence in the estimate for the two populations using the different methods (Minimum convex Polygon, Harmonic Mean and Kernel Estimator). Regarding road crossing, I sought to determine the extent and periodicity of road crossing around the home, and to determine if the road crossing may be influenced by the level of traffic.

4.2 Methods

4.2.1 Locations

Locations were chosen to be representative of the higher density housing found within a city area (City Urban environment– CU) and lower density housing typical of a village in a rural area (Rural Urban environment- RU, note a true rural environment would be outside of any conurbation). Each study location was defined by an area of 500 houses in Lincolnshire, UK: Monks Road within the city of Lincoln consisting of mainly two-storey terraced houses with small backyards (density= 858 houses/per km^2 - Fig 4.1A) and the village of Dunholme, approximately 6 km from Lincoln, where houses were typically detached with gardens (density = 149 houses/km^2 – Fig 4.1B). Each area is crossed by two major roads.

A

B

Figure 4.1: A City area: Monks Rd, east of Lincoln city centre, containing 500 houses and measuring 5.83 hectare. B Rural area, part of Dunholme village containing 500 houses and measuring 33.67 hectare.

Before subjects were recruited, the number and nature of cat-owning households was determined from an intensive postal survey of the 500 homes in the target areas (150 respondents from Lincoln and 222 from Dunholme; Chapter 2). Assuming that cat ownership in the two locations did not affect response rate, this indicated that 30% of city and 33% of rural respondent households owned cats. Of these, 15 out of the 45 city households and 20 out of the 74 of rural households were multiple cat homes.

4.2.2 Subjects

I recruited and monitored a total of 14 neutered cats (eight males, six females, age ranging from one to 15 years old; see Table 4.1) (RU cats=7, CU cats=7). Cats were recruited based on information from my survey to have outdoor access for at least half an hour a day and also returned home several times a day. Because the GPS device was worn on a collar, all cats had to be accustomed to wearing a collar before they could be included in the study. Where necessary, collar habituation was undertaken over a period of 10 to 15 days depending on the individual.

Category	Cat name	Cat age (years)	Cat sex
Dunholme (village; RU cats)	Poppy	7	Female
	Charlie	2	Male
	Billy	9	Male
	Tanhee	3	Female
	Tikka	3	Male
	Willow	5	Male
	Rio	11	Female
Lincoln (city; CU cats)	Errol	2	Male
	Boris	15	Male
	Enid	5	Female
	Lois	1.5	Female
	Sargeant	10	Male
	Simba	6	Female
	Lecter	1.5	Male

Table 4.1: Age and sex distribution of the recruited cats.

4.2.3 Tracking Protocol

Once the cats were used to wearing the GPS collar, their activity was logged for seven days, including one weekend. Owners were instructed not to change their cats' management. Time was recorded by the GPS device so diurnal and nocturnal activity could be identified. Data were recorded on a MicroSD card and downloaded after the collar's collection at the end of the study period. All data were gathered between March and May 2014.

4.2.4 Data analysis

All analyses of home ranges and distances travelled were performed using RANGES 8 (v2.13) (Kenward et al. 2008). Latitude and longitude obtained from the GPS device were converted into x,y coordinates using the TM_LL Workbook as recommended (RANGES software authors - Kenward et al. 2008). Outliers (points at the edge of the home range, which might indicate an occasional sortie outside the home range rather than the home range itself) and biological impossibilities, such as the cat moving at more than 30 metres per second were removed. This represented less than 0.1% of the data. Home ranges were estimated using a sub-sample of the data, taking one point every 15 seconds to smooth the contours (de Solla et al. 1999).

Three different computational methods were used for assessing the home range of cats over the week and comparing these between RU and CU cats: minimum convex polygon (MCP), harmonic means (HM) and kernel estimators (KE) using both 95% and 90% estimates. A MCP is obtained by linking all the data points that are at the edge of the home range, a HM utility distribution is obtained by linking every data point to an underlying chosen grid, and a kernel estimator covers each of the animal's location with a three dimensional hill, the "kernel" and the contours are obtained depending on the density of point at a given location (how much the animal has been located at this location) (Powell 2000).

MCP is a widely used method, which is resistant to problems of spatial autocorrelation (the cat's location at the time t influences the cat's location at the time t+1). However, because of the production's method, MCP is very sensitive to outliers and may include areas that are not actually used by the animal. Using 95% of data (MCP95) allowed us to compare my findings with other, similar studies (Moseby et al. 2009; Horn et al. 2011; Gehrt et al. 2013), while the use of 90% of data points (MCP90) was also considered as it produces an area estimate that is less biased by sample size (Börger et al. 2006). The harmonic means contour was calculated with location density only (which means that the calculation is based more on the density of data points rather than considering all data points including extreme ones). In this method, 95% (HM95) and 90% (HM90) of the data points were used for estimation in order to allow comparison with the other methods. Finally, I used a fixed kernel estimator fitted to location with a least square cross validation for the smoothing parameter (this allowed us the get the tightest smoothing estimation of the home ranges) using KE95 and KE90, as a third method for estimating home range size. In general, using 95% and 90% of the data points, thus excluding the 5% or 10% of points that are at the edge of the home range, allows to exclude most of the outliers and to take into account the fact that the cat may make the occasional sally out of its home range. Therefore it allows determining the cat's home range with a greater accuracy, as in "the areas that are really used by the cat".

For the core home ranges, I used 50% and 20% MCP, HM and KE, with similar calculations undertaken as used in relation to full home ranges. The 50% isopleth estimate is widely used in studying feral and wild animals (Edwards et al. 2001; Molsher et al. 2005; Livieri and Anderson 2012) but I decided to also use a 20% estimate to accommodate the fact that these cats were owned and housed in a specific location that might bias the outdoor core area to a more restricted region around the resource rich home (a phenomenon not relevant to wild or feral animals). To ensure that I had an accurate view of the weekly home range, the home range asymptote (Harris et al. 1990) was calculated for each cat using an incremental analysis with RANGES 8 (Kenward et al. 2008). I used a Spearman's rank order correlation test to establish if there was a relationship between the home range asymptote and the habitat.

I used a Friedman test to compare the three different methods (see Table 4.2 below) of home range size estimation for both groups of cats (CU/RU) using the same percentage of data points (95%, 90%, 50% & 20% isopleth). When I found a significant difference between methods, pairwise comparisons were performed to identify which methods differed, with a Bonferroni correction for multiple comparisons. Comparisons between the CU and RU cats were conducted using a Mann Whitney U test in SPSS (v19).

4.2.5 Road crossing

To investigate if cats were crossing roads, I plotted the cat's movements against a local map (using google maps) and manually counted the road crossings for each cat. Taking into account the accuracy of the GPS device, a road was considered crossed when the final position of the cat's crossing (following line of data points) was at least more than 10 metres from the edge of the road.

4.3 Results

4.3.1 Home ranges

All recruited cats provided useable data, but the number of most reliable data points with seven or more satellites logged varied with location. Overall only 33% of data points from CU cats reached this criterion, while for RU cats the figure was 60%. Five CU cats and one RU cat failed to provide adequate data for all seven days of data collection. Therefore, in order to be able to use all 14 subjects, we decided to use four days of recording to make my estimates (henceforth referred to as weekly home range/core area) as all cats had at least four days of adequate data. Days with the highest number of data points (all with 7 or more satellite fixes) were chosen for each subject. The number of data points needed to reach the home range asymptote ranged from 258 data points to 3773 data points. For each cat recruited, the number of data points was much higher than the number necessary to reach the home range asymptote. There was, however, no relationship between the number of fixes needed to reach the home range asymptote and estimates of individual cat home range size using any of the methods (95%MCP, r_s=0.23, p=0.427, 95%HM, r_s=0.18, 0.533, 95%KE, r_s=0.08, p=0.773). I found no differences in the number of fixes to reach home range asymptotes between CU cats (Mean ± SD =1552 ± 1197) and RU cats (Mean ± SD=2158 ± 1031), $F(1,11)$=2.81, p=0.122.

Although the median value for home range of CU cats (median + interquartile range MCP95 (used for comparative purposes with other studies) = 2.70 + 7.08) appeared lower than that of the rural-based urban cats (RU cats median + interquartile range MCP95 is 2.81 +2.75), there were no significant difference between the groups for any of the three computational methods (see Table 4.2). As anticipated the MCP95 method appeared to generate much higher median values for home range than either of the other two methods or even MCP 90, providing values at least twice the size of the other methods (see Table 4.1). The computational method used to describe the home range greatly affected the shape and size of the range (Figure 4.2) and potential direction of difference in size between the two environments.

Home range estimator	CU cats (ha) Median + interquartile range (IQR)	RU cats (ha) Median + interquartile range (IQR)	Mann Whitney U test U ; z	Mann Whitney U test p value
Minimum Convex polygon				
95%MCP	2.70 + 7.08	2.81 + 2.75	24 ; -0.06	1
90%MCP	1.36 + 4.10	1.68 + 1.64	23 ; -0.19	0.902
50%MCP	0.14 + 0.28	0.11 + 0.37	22 ; -0.32	0.805
20%MCP	0.05 +	0.04 + 0.06	12 ; -1.60	0.128
Harmonic Means (HM)				
95%HM	1.37 + 6.61	1.32 + 2.09	22 ; -0.32	0.805
90%HM	0.88 + 4.01	0.68 + 1.28	22 ; -0.32	0.805
50%HMc	0.10 + 0.38	0.07 + 0.16	22 ; -0.32	0.805
20%HMc	0.01 + 0.06	0.009 +	21 ; -0.45	0.71
Kernel estimator (KE)				
95%KE	1.11 + 5.66	1.85 + 2.75	24 ; -0.06	1
90%KE	0.63 + 3.35	0.78 + 1.42	24 ; -0.06	1
50%KE	0.06 + 0.21	0.12 + 0.14	25 ; 0.06	1
20%KE	0.02 + 0.12	0.04 + 0.09	30 ; 0.70	0.535

Table 4.2: Comparison of total home ranges in hectares (95% and 90 % of data points) and core home ranges in hectares (50% and 20% of data points) between city-based urban cats (CU cats) and rural-based urban cats (RU cats). Presentation of Median home ranges + interquartile range (IQR)

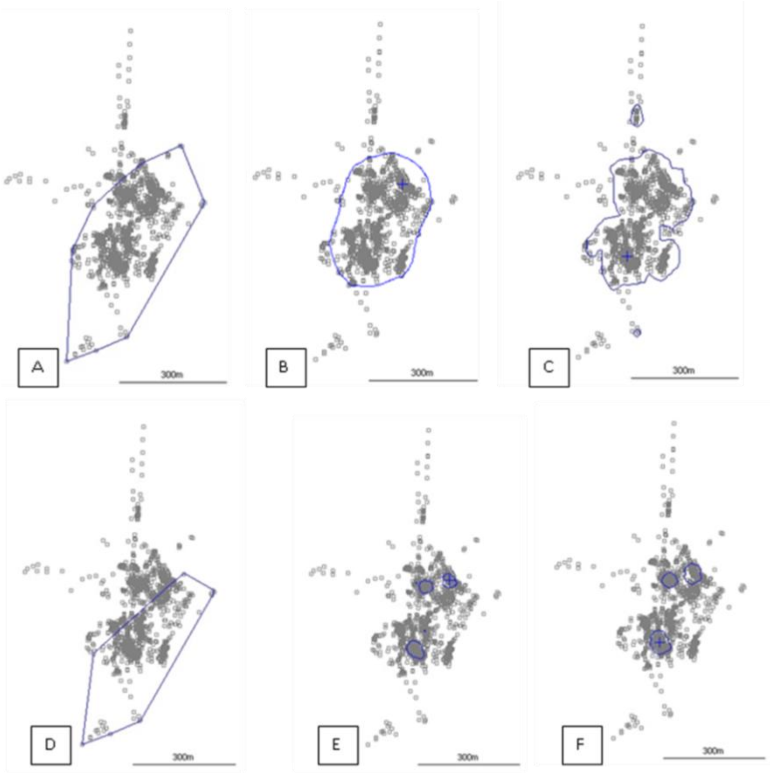

Figure 4.2: Example of variation of the size and shape of the home range estimation depending on the method used for a CU cat. A,B,C: MCP95, HM95, KE95. D,E,F: MCP50, HM50, KE50.

I found that, depending on the isopleth chosen and the group of cats, there were significant differences between the different methods in the estimates provided (see Table 4.3).

Percentage of Data Points	CU cats Friedman test	CU cats Post Hoc tests	RU cats Friedman test	RU cats Post Hoc tests
95% MCP, HM, KE	$\chi^2(2)=5.43$ p=0.066	None	$\chi^2(2)=5.43$ p=0.066	None
90% MCP, HM, KE	$\chi^2(2)=3.71$ p=0.156	None	$\chi^2(2)=0.86$ p=0.651	None
50% MCP, HM, KE	$\chi^2(2)=10.29$ **p=0.006**	KE50-MCP50 **p=0.004**	$\chi^2(2)=4.57$ p=0.102	None
20% MCP, HM, KE	$\chi^2(2)=10.29$ **p=0.002**	HM20-MCP20 **p=0.002**	$\chi^2(2)=11.14$ **p=0.004**	HM20-KE20 **p=0.048** HM20-MCP20 **p= 0.004**

Table 4.3: Comparison of estimation of home range and core area size between methods, for CU cats and RU cats.

4.3.2 Core area

There was no significant difference between groups regarding the core area for any of the three methods, regardless of whether the core area was represented by 50% or 20% of the cat's home range. However, there were significant differences between methods to evaluate the home range core area (see Table 4.3).

4.3.3 Distance travelled

Results from distance travelled per cat are presented in Table 4.4. There were no significant differences between groups of cats for the total distance travelled or the mean distance travelled per day.

Distance	Mean	Standard error	P value
Total distance travelled (km)			
Lincoln	15,436	4.382	0.437
Dunholme	19.899	3.391	
Mean distance travelled per day (km)			
Lincoln	3.859	1.096	0.437
Dunholme	4.975	0.848	

Table 4.4: Total distance travelled per cat and mean distance travelled per cat per day in kilometres, with standard error and p value.

4.3.4 Road crossing

Thirteen of the 14 cats provided useful data on road crossing. Results are presented in Table 4.5. Since depending on the cat, the number of recordings providing data is different, we also present the number of recordings. All cats but one (Errol) crossed only minor roads, i.e. roads only leading to residential areas inside the study areas.

Cat name	Number of recordings	Total road crossings	Mean road crossings per day	Minor (m) or Major (M) road crossed
Billy	8	20	2.5	m
Boris	4	0	0	N/A
Charlie	7	11	1.6	m
Enid	7	9	1.3	m
Errol	7	33	4.7	M
Lois	4	0	0	N/A
Poppy	6	23	3.8	m
Sargeant	7	3	0.4	m
Simba	8	44	5.5	m
Rio	10	15	1.5	m
Tikka	10	5	0.5	m
Tanhee	7	0	0	N/A
Willow	8	16	2	m

Table 4.5: Number of recordings, total road crossings, mean road crossings per day and type of road crossed for 13 cats in the study, regardless of the location.

4.4 Discussion

The number of fixes required to reach home range asymptote was very variable (min = 258, max = 3773), but was broadly similar to other studies (Recio et al. 2010) and was not related to home range size. This means that it is difficult to provide a simple "rule of thumb" to estimate whether sufficient data have been gathered to determine home range size. It is worth noting that in the case of owned cats, with roaming limited to around a focal home site, 3773 fixes was the maximum number of points needed to reach the home range asymptote. We recognise that intensive tracking may be necessary to have a good idea of the home range size depending on both the environment and animal's movement.

I compared three methods used to estimate home range size: the Minimum Convex Polygon (MCP), the Harmonic Mean (HM) and the fixed Kernel Estimator (KE). The finding that MCP over-estimated the home range size, and included large areas not used by the animal is well known (Powell 2000), especially when using the 100% isopleth, which is why I choose the 95% and 90% isopleth to estimate home range size. Despite this problem MCP has been used historically and so potentially allows comparison with other studies. Accepting this potentially serious limitation (as highlighted in the discussion below on the comparison of home range between CU and RU cats), the MCP95 and

MCP90 results support previous indications (Horn et al. 2011) that owned cats typically have a much smaller home range than feral cats that must hunt in order to survive. The availability of food seems to be one of the key resources determining the size of the home range (Horn et al. 2011; Hervias et al. 2014). The home ranges of wild cats (Biro et al. 2003; Sliwa et al. 2004) and some feral cats (Edwards et al. 2001; Molsher et al. 2005) cover hundreds or even thousands of hectares depending on the habitat they are living in. The home ranges of feral cats that have food available (Tennent and Down 2008) and owned cats has been reported to vary from 0.01 ha to several hectares (Lilith et al 2008; Horn et al. 2011), being 2.75 hectares on average in the current study (based on MCP95). Although it might be expected, as indicated by the use of MCP and KE, that RU cats (living among low density housing) would have bigger home ranges than CU cats (living in high density housing) as a result of the wider availability of open ground, the findings indicates that it is not the case. When considering core area calculation, I found a significant difference in the methods used for the 50% and 20% isopleth. For the 50% isopleth, I found a difference when considering the data from the CU cats (difference between MCP50 and KE50), whereas for the 20% isopleth, I found differences between HM20 and MCP20 in both groups, and differences between HM20 and KE20 for the RU cats. These results highlight the significance of the choice of calculation method depending on the environment in which they are being studied as noted by Bengsen et al. (2012). Although I found no significant differences between RU cats and CU cats' core areas using any method or proportion of the data examined, I do not consider these methods to be equal, as there are significant differences between the core area estimates depending on the method. I did not find any difference between RU cats and CU cats in the total distance travelled or the mean distance travelled per day, however the interesting finding is the number in itself. In home ranges that are on average of 2.75 hectares, which could be represented by a rectangle of 100 metres by 275 metres, cats manage to travel on average four kilometres per day. It would be difficult to compare the distance travelled between owned neutered cats that have the owner's home at the centre of the home range, to the distance travelled of wild or feral cats, which may also be entire so have a home range that would be influenced by reproduction opportunities. Moreover, in the two studies using GPS technology and studying owned and neutered cats (Hervias et al. 2014; Thomas et al 2014), there is only one mention of distance travelled, but it is the maximum distance from home,; this is not comparable to my data (Hervias et al. 2014). The result has to be interpreted with caution, because the high frequency sampling (every second) increases the possibility of error due to the relative accuracy of the device. However, this finding suggests a level of exercise difficult to reach for indoor cats, even with a very active lifestyle being encouraged. This might be an important insight on how much an indoor and an outdoor lifestyle may differ in cats. Bringing all the findings about home range and distance travelled together, I did not find any difference between groups, which might indicate that regardless of the residential location, the provision of resources (food, water, shelter) and the absence of reproductive opportunities might be the factors that determine the home range in owned, neutered cats.

Regarding road crossing, this first result shows that road crossing is very variable, depending on the day, and the cat. In the study environment most of the cats (10 out of 13) crossed roads (of varying size) on a daily basis, ranging from 2 to 16 road crossings per day. These findings are in line with a previous study on risk taking behaviour in cats (Loyd et al. 2013) even if in my study more cats crossed roads (76.9% of sample crossing roads in my study versus 45% in Loyd et al. 2013) and more often (80% of cats crossing road doing so at least once a day in my study versus less than 48% in Loyd et al. 2013). Little studied in owned cats, road crossing has been studied in foxes and it was found that they cross roads less than a model of randomly generated fox movement (Baker et al. 2007), suggesting that they actively avoid crossing roads. In my study, despite having two major roads in the two areas of study, only one cat (Errol) crossed a major road on a daily basis, and in this instance the entrance of the house was on that major road and a green space with trees and bushes was available directly across this major road. The people's perception of risk of being involved in a road traffic accident is therefore supported by my result, even if the cats seemed to avoid the major roads in my study.

4.5 Conclusion

GPS technology is relatively simple to use and can be an effective way of tracking the behaviour of owned cats even in complex environments, but its accuracy depends on making appropriate methodological decisions according to the hypotheses being tested. There is a trade-off between the number of fixes desired and battery life which needs to considered at the outset, and the impact of the final decision needs to be clearly justifiable and acknowledged in the interpretation of results. In an urban environment, thousands of fixes ensure the need to reach an asymptote is achieved, but choosing the right method depends on the environment, shape of the area being investigated and its nature, since this will affect the percentage of isopleth chosen (e.g to estimate total home range versus core area). Regardless of the location, cats that are allowed outdoor seem to exercise a lot which is important when investigating differences between indoor and outdoor lifestyle. Finally, in the case of owned cats, it allowed me to track the number of road crossings. This is important to both cat owners and non-cat owners who consider being exposed to a road traffic accident is one of the major risks for an outdoor cat. In general, the majority of owned cats that are free to roam outside appear to cross roads on a daily basis, which is a cause for concern.

Chapter Five

A review of the risks for a domestic owned cat going outside

5.1. Introduction

Cats are thought to have been domesticated around 9500 years ago (Vigne 2004) and have spread around the world, fulfilling very different roles when living alongside humans: they were historically used for pest control, kept as companion animals, and venerated as a religious icon in ancient Egypt and India (Turner and Bateson 2000). Nowadays they are one of the most popular companion animal species, and the number of owned cats in the United Kingdom is estimated at around 11 million (Murray et al. 2010; PAWS report 2015). Even if the roles originally linked to cat ownership still exist (i.e. acting as means of pest control and giving company to their owners), the cats' role as a companion animal has gradually increased. The way they are managed as pets has evolved, however, with different types of care (e.g. cats kept indoors, specialised food and veterinary care). A primary factor in this management is the environment in which humans, and by association their cats, now live. This environment has been subject to considerable change as a consequence of human population growth and increased urbanisation (Pateman 2011). Since 1960, the human population of Europe has increased by 127 million (Eurostat 2004) and the population of the UK by 10.5 million. Largely as a result of industrialisation and improved economic opportunities, human population densities are very different across countries and regions. For example, Greater London has a density of 14,503 people per square kilometre, compared to 122 people per square kilometre for the county of Lincolnshire (ONS 2013).

As human population density and urbanisation has increased, land cover and land use has changed. Specifically in the 20th century, urban settlements numbers are highest in the developed countries, but urban growth is most rapid in developing countries. The general landscape has changed, and with it the environment where cats live (Meyer and Turner 1992 for review on the global land cover/land use change). This changing environment is likely to have a significant impact on the large pet cat population occupying this space. When it comes to the management of their cats, cat owners may try to make informed decisions, weighing up the various advantages and disadvantages (e.g. giving vs. not giving access to outdoors) in order to maximise the welfare of their cat. This decision-making process can result in a whole range of management outcomes, from cats being confined indoors to them being given unrestricted outside access (Clancy et al. 2003); each presenting different risks for the cats' welfare in different ways.

When it comes to deciding upon whether or not to give owned cats outdoor access, this is likely to include the consideration of real as well as imagined risks, as well as being influenced by existing beliefs held about cats (e.g. Turner and Bateson 2000; Toukhsati et al. 2007). If some risks are given more attention (e.g. in veterinary clinics or media) then the perceived risk may be inflated. Risk depends on both the severity of a hazard and the likelihood of it occurring, so it is important to establish the known risks for cats that are allowed outside, how serious they are for the cat (i.e. severity) and how frequently they are encountered (i.e. prevalence). To manage risk effectively it is essential to know whether/how owners can protect their cats against them (i.e. potential interventions). Finally, given that cats have a close association with humans, it is also important to appreciate the hazards that cats can pose to humans, since an increased risk to humans may affect the management of the cat and thus its welfare less directly.

The aim of this review is to provide an overview of the specific risks posed to outdoor cats including their likely prevalence, severity and subsequent impact on welfare, as well as discussing potential means to reduce them, and so does not give a detailed and exhaustive study of each risk. The review encompasses only those risks that are specific to cats that wander outside and have the potential to cause serious illness to either the cats themselves or their owners.

5.2 Risks to free roaming cats

Risks can be categorised as physical risks and psychological risks. The former can be further divided into infectious and non-infectious risks, each of these might be further divided, thus infectious risks include those from different classes of organism, bacteria viruses, protozoa, helminths etc, while non-infectious risks can be divided into risks of injury (e.g. caused by road traffic accidents or fighting or falling from a roof) and risk of toxic hazards (plant or chemical poisoning). In the next section I consider each of these, incorporating discussion of potential interventions and ways to mitigate the risks.

5.2.1 Physical risks to the cat’s welfare

From Chapters 2 and 4 it is clear that as well as road traffic accidents being perceived as being the greatest hazard encountered by cats that go outside, there is also an actual risk, with most outdoor cats crossing roads regularly. Accordingly, I will focus first on the risk of injury by road traffic accident, or animal/vehicle collision before other risks specifically associated with being outdoors.

5.2.1.1 Risk of Injury

Animal vehicle collision or road traffic accidents (RTA)

Road traffic accidents involving an animal-vehicle collision are numerous around the world whether it involves wildlife (Steiner et al. 2014; Zuberogoitia et al. 2015) or domestic animals (Massei and Miller 2013; Rochlitz 2003a). However, in relation to cats, there is little direct information about the number of cats involved in RTAs per year, and the number of fatalities caused by these RTAs. In the UK, they rank as the fourth most common cause of death after old age, cancer and renal failure, according to a questionnaire with 182 answers developed by Rochlitz et al. (2001), which gives us an indication of the scale of the problem but not a number to rely on. In 2006, the insurance company Pet Plan suggested that nearly 250 000 cats died each year on UK roads (http://www.dailymail.co.uk/news/article-418199/230-000-cats-run-year.html). Hence RTAs appear to be a tremendous threat to the welfare of outdoor cats. Although there are several reports relating the consequences for cats of being hit by a car (Corr 2009, Meeson and Corr 2011), there are far less that have investigated the factors influencing why cats are caught in RTAs. In 2000-2001, Rochlitz (2003a, 2003b) studied the factors that could predispose cats to RTAs focusing on a population of owned cats brought in to six veterinary clinics in Cambridgeshire, UK. Rochlitz (2003a, 2003b) showed that the RTA cats (cats involved in a RTA) were most frequently young, male (both entire and neutered) and non-pedigree in breed, and it appeared that neuter status was of less importance than being young (between seven months and two years). Although juvenile cats (< six months old) were not widely involved in RTAs in this study, it may be because, in this particular local population, owners prevented their cats from going outside before being fully vaccinated (i.e. three to four months on average, which is a large part of the time up to six months). As for the factor "pedigree", Rochlitz hypothesised that owners of pedigree cats may keep them inside most of the time. In addition, pedigree cats are more likely to be indoor-only cats (Toribio et al. 2009) – due to perceived risks of outdoors (being stolen, being costly to replace, and unwanted breeding with non-pedigrees). Rochlitz (2003a, 2003b) also tested the factor "time spent outdoors". Younger cats appeared to spend more time outdoors which could partially explain the finding that they are more at risk of being involved in a RTA than older cats. However, there was no difference in the "time spent outdoors" when adjusted for age between the control cats and the cats involved in RTAs. So a key factor influencing risk of RTAs could be the behaviour of the cat when it is outside. For example, although RTA cats may not travel further away from the home than non-RTA cats or spend more time outside, they may be more likely to engage in risky behaviour, such as repeated road crossings, potentially because they have less experience of ‘near misses’ compared to older cats that have survived (exposure risk being an inevitable consequence of longevity) . These experiences may provide the opportunity for cats to learn about how to reduce risky behaviour (e.g. less or more suitable road crossings).

Reducing the risk to outdoor cats of being involved in RTAs is very difficult. In Rochlitz’s findings (2003a, 2003b), there is a trend for cats to be more involved in RTAs at night, so keeping the cat in at night might be part of the solution. A more drastic solution would be to keep the cat indoors permanently. Another solution would be to supervise the cat’s access outside, keep the cat on a harness when outside, or restrain this access by using an effective containment system. However this latter solution involves costs that not every owner may be prepared to face, i.e. the cost of installing the chosen containment system but also the time needed for training and supervising the cat.

Agonistic encounters and malicious injuries

Cat population densities typically reflect human population densities, and both densities increase in an urban setting (Sims et al 2008), although distribution of cats can depend on the socio-demographic factor of the neighbourhood (Finkler et al. 2011a). As cat population density increases so does the risk of agonistic encounters between them. Those agonistic encounters between cats may lead to injuries that commonly turn into abscesses (Love et al. 2000). One way of mitigating the specific risk of cats fighting other cats is neutering, as it reduces aggression behaviour between cats (Finkler et al. 2011b). Agonistic encounters may also be interspecific encounters (e.g. cat-dog, cat-fox) and may lead to more serious injuries (Kilic and Derincegoz 2012).

Malicious injuries are those inflicted upon cats by humans that intend to harm them. Unfortunately they are not uncommon (McGuiness et al 2005; de Siquieria et al. 2012). Although dogs seem to be the most commonly reported species to be abused (for example in Ireland: McGuiness et al 2005), cat reports seem to be second in number (Williams et al 2008). The injuries are usually serious and may lead to death (RSPCA prosecution report 2013). The extent to which unreported abuse occurs is unknown, but it may be easier in the cat as people may trap a cat found outside alone or find it easier to dispose of a killed cat, without being detected.

A way to suppress the risk of both agonistics encounters and malicious injuries would be to keep the cat indoors; so that only persons and animals that are trusted may have access to the cat. Another possibility that would greatly reduce the risk but not suppress it would be to have an effective containment system in place, because most humans would be admitted on the property through the owner, and reducing the space the cat is free roaming in will reduce the probability of agonistic encounters.

Falls from heights and getting trapped

One of the potential drawbacks of living in an apartment is the risk of falling from a window or a balcony, also known as the "high-rise syndrome" (Nakladal et al. 2013). The prevalence of this problem is unknown, but a number of features associated with the risk of harm have been documented. Cats usually sustain injuries if they fall from a height higher than two floors (Duhautois et al. 2010) and the injuries may include, for example, lung contusions, appendicular fractures, carpal injuries and pancreatic ruptures (Duhautois et al. 2010; Liehmann et al. 2012; Nakladal et al. 2013). According to a retrospective study of 204 cases by Duhautois et al. (2010), the fall is fatal in 11% of cases. Falling from heights is thus a serious risk which can only be mitigated by not allowing cats in high height dwellings to go outside, or securing the outside space with a mesh which will prevent escape. As for cats living in houses, the only way of preventing them from falling off a roof would be to put in place an effective containment system.

Another risk for outdoor cats is the risk of getting trapped in a locked building. The consequences are directly related to the time during which the cat is trapped. Getting trapped may result in weight loss if the cat is trapped for more than a day; and unfortunately (and very rarely) in death by starvation or thirst if the cat cannot escape, but could also result in the cat being poisoned, for example by licking spilled chemicals in a garage because of the thirst.

5.2.1.2 Risk from toxic hazards

The risk of a cat being poisoned when it has access to the outdoor environment incorporates contact with (mostly via consumption of) a range of both man-made and naturally occurring substances including pesticides, insecticides, plants, chemicals and anticoagulants. Again the prevalence of this problem remains unknown, although risk factors are identifiable.

In Europe, cats are the second most common non-human species to be victims of accidental poisoning after dogs (Berny et al. 2010). Cats are particularly sensitive to plant poisoning because they lack the capacity for glucuronidation as a result of hypercarnivory (Shrestha et al. 2011), but frequently chew leaves (Berny et al. 2010). The Liliacae family – containing many ornamental plants typically found in gardens and flower arrangements (Fitzgerald 2010) pose a particular risk to both indoor and outdoor cats. In the Liliacae family, the genera Lilium (lilies) and Hemerocallis (day lilies) are nephrotoxic; the genus Allium (onions) can cause haemolysis and the genus Narcissus (daffodils) contains alkaloids that can cause gastrointestinal irritation (Fitzgerald 2010). Passive contamination may occur via the pollen of some of these species, followed by ingestion from grooming. It is for this reason that the stamens may be removed from some cut flowers.

For poisoning by pesticides and insecticides, wandering cats can be contaminated 'passively' by being in a field as it is being treated with such chemicals (e.g. carbamates such as carbofuran or pyrethroids such as permethrin), which can elicit digestive and neurological signs and may even lead to death (Berny et al. 2010). Anticoagulants (e.g. bromadiolone, difenacoum, difethialone) are widely used for rodent pest control throughout the world, with poison-laced baits placed in affected areas (e.g. near food stores). If these baits are accessible to non-target species such as cats, they can be consumed directly. However, another way to be contaminated is for cats to eat prey that have themselves consumed the baits (Valchev et al. 2008). Thus, even correct use of the rodent poisons can result in the indirect poisoning of cats. The symptoms are internal and external haemorrhage that can lead to death (Kohn et al 2003; Valchev et al. 2008). Symptoms are often delayed from absorption (e.g. up to 12 hours; Valchev et al. 2008) so it is often difficult to find where the poison is located in the environment, meaning there may remain an ongoing risk for cats since the source may remain unknown. Finally, poisoning by a range of toxic chemicals can happen throughout the indoor and outdoor environment, for example the consumption of vehicle anti-freeze, which may be induced by thirst if the cat is trapped in a locked garage, for example. The symptoms depend on the absorbed quantity but in cats can result in coma and death. However, if treatment is given within four hours of ingestion (Janczyck and Wiechete 2002), the cat may recover.

In order to mitigate the risk of cat poisoning, owners may secure their property and rely on community communication and awareness outside the boundaries of the property, or may decide to contain the cat to within the boundaries of their property by using some form of containment system, or may decide to confine the cat to the house, provided that they removed any plants or products that might be dangerous for the cat.

5.2.1.3 Risk of Infection

Infectious risks come from a range of bacteria, viruses and parasites; some of which are not dependent on direct contact for transmission. Table 5.1 lists the infectious risk, the pathogen, the symptoms and prevalence, means of transmission and potential means to mitigate the risks, with references. Bacteria are presented in red, viruses in green, and parasites in blue.

In the risk of infection by Bacteria, two genera stand out: *Bartonnella spp.* and *Mycoplasma spp.* Cats are usually healthy carriers of *Bartonnella spp.* but this bacteria is responsible for the Cat Scratch Disease which can lead to severe symptoms in humans, especially if they are immunocompromised. The best to fight against infection is to treat the cat against fleas. Regarding *Mycoplasma spp.*, symptoms can be life-threatening in cats and transmission occurs during aggressive interactions, so neutering is one of the ways to fight against it, as well as avoiding contact with other cats.

In the risk of infection by viruses, five viruses (without being exhaustive) are very common: the Feline Immunodeficiency Virus, transmitted by blood and bites and the Feline Leukemia virus transmitted by saliva and nasal secretions, both leading to a reduced life expectancy by way of a compromised immune system. The Feline Herpes Virus and Feline Calici Virus, a pair that form the “cat flu” or Upper Tract Respiratory Disease, are transmitted by close contact. Finally the Feline Parvovirus, which may lead to cat death by attacking the digestive and immune system, is transmitted via cat faeces. The essential way of preventing symptoms and fighting against transmission is to vaccinate the cat.

In the risk of infection by parasites, the cat flea is present worldwide, can trigger symptoms on its own (irritation or allergy due to flea bites) or be a vector of bacteria such as *Bartonella spp.* Toxoplasma gondii is a zoonotic parasite, cats are healthy carriers but the parasite is especially dangerous to pregnant women leading to abortion or deformation of the foetus and can be transmitted via cat faeces, even if the cat is not the only way of transmission. Pregnant women should avoid being in contact with cat faeces and cleaning cat litter trays. Finally, in the risk of infection by parasites, cats can be affected by the commonly called “worms”, which are represented by the Nematodas, Platyhelminths, *Giardia spp.* and *Cryptosporidium spp.* For all of them, transmission occurs with the ingestion of eggs shed by another cat or of another infective stage in zones near water. Sometimes the external environment is essential to complete the cycle, specifically linking the risk of infection to free roaming cats. The essential way of fighting against those parasites is to deworm the cat using appropriate products, four times a year (see Table 5.1).

Pathogen	Signs and symptoms	Seroprevalence (antibodies present in blood) and Prevalence (isolation of the pathogen itself)	Means of Transmission	Mitigating the risk
Bartonella spp *Bartonella henselae* type I and type II Bartonella clarridgeiae	In cats: Healthy carriers (Breitschwerdt and Kordick 2000; Chomel 2006). In Humans: **Cat Scratch Disease**: Increase in local lymph nodes (Chomel 2006; Nakemata 2010) **Immunocompromised patients**: prolonged fever and bacteraemia, also bacillary angiomatosis (a cluster of benign tumours derived from blood vessel cells ; Chomel 2006)	Seroprevalence range: from 1% in Norway and Sweden (Bergh et al 2002; Hjelm 2002) to 93% in North Carolina, USA (Nutter et al 2004) Associated percentage experiencing **bacteraemia** usually lower. Higher in feral cats than in owned cats (Boulouis et al 2005) In UK, seroprevalence is around 40% and bacteraemia around 10% (Boulouis et al. 2005)	Vectors between cats: Major: Fleas via flea faeces (Chomel et al 2006) Minor: Ticks and biting flies Cat- Human Transmission: By scratches or bites	Flea treatments via topical application of specific medication containing knock down agent and growth inhibitor Avoid contact with other cats, e.g. keep indoors

Pathogen	Signs and symptoms	Seroprevalence (antibodies present in blood) and Prevalence (isolation of the pathogen itself)	Means of Transmission	Mitigating the risk
Feline haemotropic mycoplasmas Mycoplasma haemofelis (Mhf) Candidatus Mycoplasma haemominutum (CMhm) Candidatus Mycoplasma turicensis (CMt)	Depending on the strain, asymptomatic to severe, life-threatening anaemia (Jenkins et al 2013)	Prevalence (DNA isolation): New Zealand (Jenkins et al 2013) Mhm 25% Mhf 7.5% Mtc 4.5% USA Mhm 23.2% Mhf 4.8% Mtc 6.5%	Aggressive contact between cats with exchange of blood (Jenkins et al 2013)	Neutering to reduce aggressive contacts (Finkler et al 2011b) Avoid contact with other cats, e.g. keep indoors
Feline Immunodeficiency Virus (FIV)	Immunosuppression: problematic secondary infections, reduced lifespan and welfare (Hosie et al 2009)	Seroprevalence range: Highly variable from 0.7% to 26 % depending on the subtype and the region (Yamamoto et al 2007)	Blood and bites, through aggressive or sexual contact (Natoli et al 2005)	Neutering to reduce aggressive and sexual contact (Finkler et al 2011b). Vaccination not recommended in Europe (Lecollinet and Richardson 2008) Avoid contact with other cats, e.g. keep indoors

Pathogen	**Signs and symptoms**	**Seroprevalence (antibodies present in blood) and Prevalence (isolation of the pathogen itself)**	**Means of Transmission**	**Mitigating the risk**
Feline Leukaemia Virus (FeLV)	Immunosuppression: problematic secondary infections, reduced lifespan and welfare (Lutz et al 2009)	Seroprevalence range: 2.3% in North America (USA and Canada) (Levy et al 2006) Around 1% in western Europe (Hellard et al 2011 for France) Up to 18% when no step are taken to reduce the prevalence (Hosie et al 1989)	Saliva and nasal secretion mainly during grooming (Lutz et al 2009) sometimes in milk (Pacitti et al 1986)	Vaccination against the virus after testing and finding the cat negative for antibodies Avoid contact with other cats, e.g. keep indoors
Feline Herpes Virus (FHV) and Feline CaliciVirus (FCV)	**Upper Tract Respiratory Disease**: sneezing, coughing, drooling, eye watering and, for the more serious cases, significant respiratory distress (Coyne et al. 2006)	Prevalence range (virus isolation): UK 6% to 75% (Coyne et al 2006)	Close contact between cats via ocular nasal and eye secretions	Vaccination available against both viruses Avoid contact with other cats, e.g. keep indoors
Feline Parvovirus (FPV).	Kitten are more susceptible: diarrhoea, lymphopenia, neutropenia (Truyen et al 2009)	Seroprevalence range: Few data available on seroprevalence of naturally infected cats (Truyen et al 2009)	Via cat faeces, persistent in the environment for months	Vaccination available

Pathogen	Signs and symptoms	Seroprevalence (antibodies present in blood) and Prevalence (isolation of the pathogen itself)	Means of Transmission	Mitigating the risk
Ctenocephalides felis	Healthy carriers to dermatitis	Worldwide infestation (Rust and Dryden 1997)	One adult cat to another Host invasion at first emergence (Franc et al 2013)	insecticide to fight against fleas Avoid contact with other cats, e.g. keep indoors
Toxoplasma gondii	Adult cats, asymptomatic to diarrhoea (Beugnet and Bourdoiseau 2005) **Zoonosis for humans:** toxoplasmosis leading to abortion or deformation of human foetus (Beugnet and Bourdoiseau 2005)	Seroprevalence: 11% in Bangkok (Jittapalapong et al. 2007) 18.2% in Germany (Opsteegh et al 2012)	Ingestion of contaminated soil and/or water (e.g. eggs are found in faeces) Ingestion of tissue cysts Via the placenta (Opsteegh et al 2012)	**Management avoiding risk factors for cats:** a history of being a stray; the presence of a dog in the household; hunting behaviour; and being fed raw meat. (Opsteegh et al 2012) **For humans avoiding risk factors:** pregnant women should wash vegetables; eat well cooked meat; avoid contact with cat faeces (Beugnet and Bourdoiseau 2005)

Pathogen	Signs and symptoms	Seroprevalence (antibodies present in blood) and Prevalence (isolation of the pathogen itself)	Means of Transmission	Mitigating the risk
Nematodas	Ascarids: weight loss, anorexia, diarrhoea, vomiting, intestinal obstruction. **Zoonotic in humans** Ancylostomes: blood loss, anaemia. **Zoonotic in humans, larva migrans (**skin penetration by the larva) (Bowman et al. 2006).	Highly variable depending on region of the world	Ingestion of eggs shed by another cat	Deworming four times a year (Epe 2011) – does not prevent infestation, but minimises time of exposure
Platyhelminths (cestodes)	**In cats:** weight loss, anorexia, diarrhoea, vomiting, anaemia. Zoonosis in humans: Vomiting, diarrhoea Taenia and Dipylidium; Petavy et al. 2000, Dyachenko et al. 2008	Highly variable depending on region of the world	Ingestion of eggs shed by another cat External environment essential to complete cycle	Deworming four times a year (Epe 2011)– does not prevent infestation, but minimises time of exposure keep indoors

Pathogen	Signs and symptoms	Seroprevalence (antibodies present in blood) and Prevalence (isolation of the pathogen itself)	Means of Transmission	Mitigating the risk
Giardia duodenalis Giardia enterica Giardia cati Cryptosporidium felis Cryptosporidium parvum	Giardia: **In cats:** asymptomatic or gastro-intestinal dysfunction (Pallant et al 2015) **Zoonotic in humans:** diarrhea, dehydration, abdominal discomfort, malabsorption and weight loss. (Buret 2008) Cryptosporidium: In cats: young animal develop symptoms, diarrhoea (Thompson et al 2008) **Zoonotic in humans:** malabsorbtive diarrhoea (Thompson et al 2008)	Giardia: Very variable **prevalence** depending on the method used: 5.2% with indirect fluorescent antibody test (Nutter et al 2004) 80% with PCR method (McGlade et al 2003) Cryptosporidium: Seroprevalence range: 8.3% - 87 % (Fayer et al 2006) 6.5% (Nutter et al 2004)	Ingestion of eggs shed in the environment for both Geni and also ingestion of infective stage as a reserve in the environment, near water (Thompson et al 2008)	Deworming four times a year– does not prevent infestation, but minimises time of exposure. Vaccination against giardia is questionable (Stein et al 2003) keep indoors

Table 5.1 List of the infectious risk, the pathogen, the symptoms and prevalence, means of transmission and potential means to mitigate the risks.

Most of the infectious risks may be mitigated by following a careful vaccination, deworming and fighting against flea program, and neutering the cat.

Risks to the physical health of a cat are numerous. The risk of injuries and poisoning, whatever the cause, would be greatly reduced if the cat was contained to its owner's property boundaries, and some of them suppressed completely if the cat was confined to the owner's house. Likewise, the infectious risks would be reduced by any type of containment, simply by reducing the probability of encounters with another cat, i.e. potential carriers of infectious disease. However, if the cat was to be contained to its owner's property, there would still be a risk due to potential animal faeces being dropped on the property or direct encounters on this land. Again, confining the cat to the house would suppress this risk.

After reviewing the risk to the physical health and subsequent threat to its welfare, I will now address the risk of psychological stress that can result from a cat being allowed to go outside.

5.2.2 Psychological risks to welfare

It is often said that being allowed outdoors is enriching for cats, and cat owners do find there are benefits for a cat from going outside (see Chapter 2); indicating that this has a positive psychological effect on their welfare; but being allowed outdoor is being allowed into an environment which has unpredictable features, and where the cat has little initial control over events. Nonetheless, cats are able to learn (McCune et al. 2008, Sherman et al. 2013, Mayes et al. 2015) and discriminate between positive and negative associations (Tami et al. 2011), and so they may be able to adapt in time. However, as discussed in Chapter 1, control and predictability are two key parameters which influence the perception of an event or a series of events, and thus influence the welfare of a cat (Basset and Buchanan Smith 2007). Accordingly, complex environments over which they may have little control can be stressful, as may indoor environments which are highly predictable (Wiepkema and Koolhaas 1993) but for different reasons. Both the inherent psychological features of the outside environment (aversion, novelty, etc) and learned associations with certain physical and social features may pose psychological risks to a cat's welfare. Physical risks to the cat's health may thus have a psychological consequence. Cats that are allowed outside could experience negative events such as a road traffic accident, an injury from a fall; an agonistic encounter (intraspecific: cat or interspecific: dog, fox) or a malicious injury from a human. If one or several of these events were to occur, once or repeatedly, and very likely cause pain, the cat may perceive certain elements (to a greater or lesser extent) of its outside environment as hostile. In this situation the environment is not a source of extended space to exercise, explore, hunt (i.e. enrichment) but a stressful place where the cat has to be alert for potential threats; with aversive memories possibly triggered by specific cues such as the olfactory signals of an aggressive neighbour cat (Mendl et al. 2001). Thus the cat's welfare may be negatively impacted by its experience of the outside environment. For example, a cat that had agonistic encounters with conspecifics that marked their passage in this cat's garden by spraying could be stressed about going outside in its owner's garden (http://www.bbc.co.uk/programmes/articles/1xFchzjJFzFRpRPqkRl5wdm/tigger encounter with Minky, the stressed cat, starting at 2mn25). There is no simple rule that can be applied in general. Each case must be viewed on its own merits.

As stated earlier, some of the risks mentioned above may be alleviated by the use of an effective containment system or cat being accompanied (e.g. leash). If the cat is contained to its owner's property and the property is secure, then the risk of road traffic accident, fall and malicious injuries is greatly reduced. A sensible and robust fencing may avoid the intrusion of a dog and potentially other predators but it would not prevent a non-resident cat from coming into the contained area and the associated risks. The ultimate solution would be to confine the cat to its owner's house, and live an indoor lifestyle.

5.2.3 Indoor lifestyle

Living indoors, provided that the house is secure and that the cat does not have access to any products or plants that would harm it, would suppress the risks mentioned above. The indoor lifestyle is promoted in the USA, and 55% to 60% of cats have an indoor lifestyle (Harbison et al. 2002; Clancy et al. 2003). In the UK, the percentage of cats kept indoors only has increased over time (11% in 2011; 24% in 2015 PAWS report 2015). However, living indoors also has its drawbacks: in Chapter 2 my findings showed that the level of exercise that an outdoor cat may perform is very difficult to reach indoors. Being less active may lead to obesity, which is associated with a variety of serious diseases: diabetes mellitus, cardiovascular problems, and osteoarthritis (German 2006; Passlack and Zuntek 2014). Moreover, some studies point to the fact that being housed indoors may increase the risks of Feline Urological Syndrome (Walker et al. 1977); dental disease (Scarlett et al. 1999a); and obesity (Rowe et al. 2015). Living indoors can also be very frustrating for cats and elicit behavioural problems (Jongman 2007; Herron 2010), which are the primary reason for giving up cats (Salman et al. 2000). Therefore, being housed exclusively indoors does not seem to be the appropriate solution.

5.3 Conclusion

There are numerous risks of various quality, severity and likelihood facing a cat that is allowed outside of the home. Many of the infectious risks can be mitigated by following a careful management program (including neutering, vaccinating, deworming and treating the cat against fleas and ticks), which demands a time and cost investment by owners. However, the risks of injuries such as a road traffic accident and toxic hazards are very difficult to mitigate without introducing supervised access outside or an effective containment system. Little research has been done into containment system and the potential impact it may have on the cat welfare, although sweeping and unjustified generalisations are often made. In the next chapters (Chapter 6, 7 and Chapter 8), the welfare implications of a specific electronic containment system, that provides some of the benefits associated with outdoor access (discussed in Chapter 2) is evaluated through a series of scientific studies.

Chapter Six

Cat containment studies

Methodological development

This chapter describes the methods used during the field study investigating the impact of an electronic containment system on cat welfare. The work focuses on methods which give insight into the impact of this specific containment system on the cat's affective state.

6.1 Containment system, subjects, recruitment process

6.1.1 Containment system tested in the study

The containment system tested in the study was the system sold by FREEDOM FENCE®. It consists of a transmitter (model FF1010) suitable for small to medium gardens and alleyways or model ProTx-1 for large and very large gardens (http://www.freedom-fence.co.uk/pet-containment/catalogue.php?id=4 2015).The transmitter is sold with a boundary kit of 100 metres rolls of wire with splices and training flags. The animal wears a receiver mounted on a collar, model ProLite™, with 10 levels of electric correction available, water resistant, with a time-out safety of 20 seconds (should the cat be caught in the signal field) and weighing approximately 40g (http://www.freedom-fence.co.uk/pet-containment/catalogue.php?id=10).

Each person who installs the system receives a training and installation manual, and representatives of the company are available to install the system and help with the cat's training. During the training phase, the boundaries are signalled by small white flags that are stuck into the ground at cat's level.

6.1.2 Subjects: recruitment process, periodicity of visits and location of households

The experimental protocol was approved by the University of Lincoln Ethics Committee.

Subjects were cats volunteered by their owners. Three groups of cats were defined:

- a group of cats that had experienced the electronic containment system FREEDOM FENCE® for more than one year, referred to as the 'Already have a Fence group' (AF group),
- a group of control cats that had access outside (i.e. being allowed outside at least one hour per day) and with no specific containment system in place, referred to as the 'Control group' (C group),

- A group of cats currently unconstrained by an electronic fence system, but whose owners were about to install the electronic containment system, referred to as the 'Before and After group' (BA group).

Given that this study was carried out on cats that experienced the electronic containment system of a specific manufacturer, i.e. FREEDOM FENCE®, the AF group and the BA group were recruited through contact with companies that supply that particular system. For the AF group, list of past clients were provided by the company, and for the BA group, a flyer was designed and distributed to prospective clients by the supplying company. Once the client agreed with the supplier to give personal details to the research, the experimenter contacted the client. The C group was recruited via a press release advertised in the Lincolnshire and Derbyshire press, and online on cat-related websites (e.g. http://www.yourcat.co.uk/ ; http://www.feline-friends.org.uk/index.htm).

For each volunteer agreeing to take part, the same protocol was followed. First, a contact email was sent to ensure that the volunteer was happy to receive documents describing the study in detail (i.e. list of inclusion and exclusion criteria for the cats, description of the tests and periodicity of visits needed, see Appendix 2). Then, if the answer was positive, the documents were sent together with an informed consent form (see Appendix 3 for example of a consent form). Once the volunteer confirmed consent, a telephone call was made to answer any questions from the volunteer and discuss the visiting schedule. After that, a reminder email was sent approximately one week before each visit.

The cat inclusion/exclusion criteria were determined according to the maturity of the cat, with the intention to exclude any parameters that might influence behaviour (e.g. reproductive distractions, medication). Hence the study included neutered cats from any breed or type, one to fifteen years of age, male or female, in a healthy condition and not receiving any long-term health or behaviour treatment. The study therefore excluded entire cats, lactating female cats and those whose kittens were less than two months old. Also excluded were cats that did not tolerate being touched or handled in any way because, although it might have meant missing out on those cats that could be most influenced by the containment, all the tests of affective state except one (i.e. the unfamiliar person test, see later) required a certain degree of human contact and so cats that would not tolerate any human contact or would not stay in the same room as the researcher would have responded only to the researcher's presence which is not the object of the study. Also, the purpose of the study was not to increase the cat's stress and it would have been the results with those specific cats. Only one cat was excluded from participating in the study because it was too apprehensive.

Regarding human volunteers, the study excluded AF and BA volunteers from Wales as the electronic containment systems are banned by law in Wales. Also excluded were households that had gone through a change in lifestyle in the three months before the study began, e.g. moving house, moving a lot of furniture, having work done in the house (like building a conservatory, redecorating, painting rooms), changes in the household like arrival of a new baby, a new person moving in, because disruption such as those listed can influence the cat's behaviour and affective state (Levine et al 2005; Neilson 2004; Stella et al 2011).

Cats included in the study each underwent a series of four behavioural and cognitive tests, and the cat owners filled in one questionnaire per cat and per visit.

- The BA group of cats were tested a week before the system's installation to assess their usual behaviour, then 10 to 15 days after the installation to assess the short-term effect of the system, then 10 to 14 weeks to assess the longer term effect of the system (see Chapter 7). In other parts of the wider project that are not part of this thesis: BA cats performed a passive avoidance test related to the training.
- The AF group were tested once, but after they had experienced the system for at least one year which allowed us to determine potential long-term effects of the system. In other parts of the wider project that are not part of this thesis: AF cats included in the study also wore modified collars in order to gather information about the number of warning and shocks received during three days,
- The C group was tested in order to compare their results to the AF group.

Volunteer households were located all over the United Kingdom as shown by Figure 6.1.

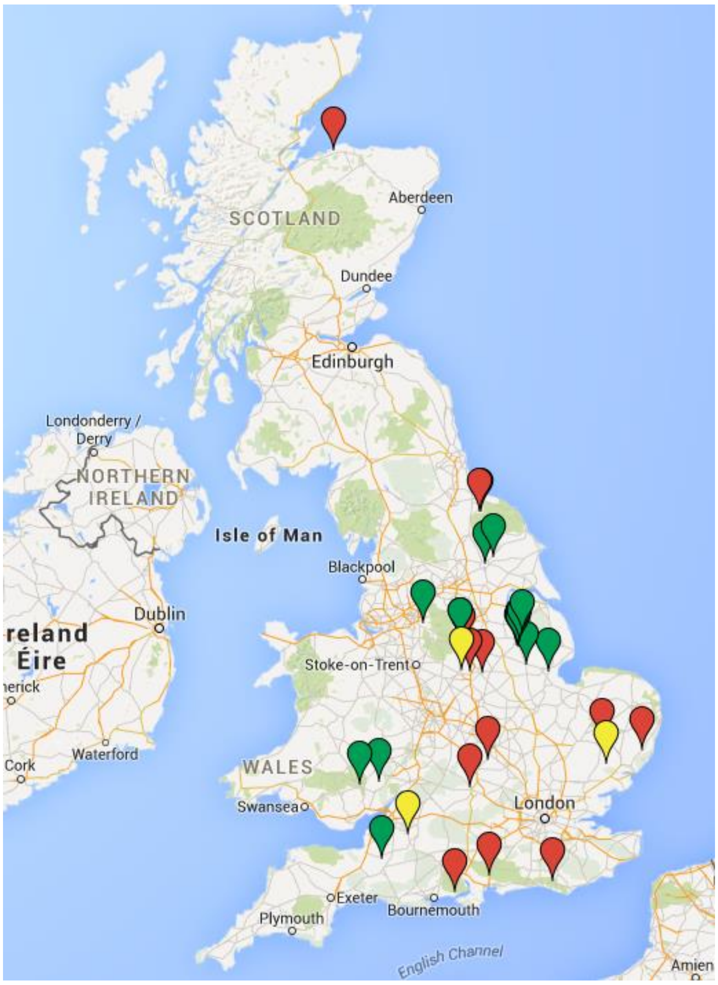

Figure 6.1: Map of volunteers' households. BA group (3 households, 4 cats): yellow pins; AF group (13 households, 23 cats): red pins, C group (14 households, 23 cats): green pins.

6.2 Assessing affective state in relation to the containment system

6.2.1 Introduction

Environmental changes can affect a cat's behaviour and welfare. For example, changes in the routine such as changes in caretakers, unpredictable loud noises and introduction of dogs nearby can trigger dysorexia (eating less) and elimination problems (urinating and defecating outside the litter tray; Stella et al. 2011). Spraying problems can also appear during the introduction of a new person or animal in the household (Neilson et al. 2004); and inter cat aggression can follow the introduction of a new cat in the household (Levine et al. 2005). Cats are thus sensitive to change and any change in the household should therefore be introduced carefully. The electronic containment system is clearly a change in the cat's usual environment, something new it has to learn to cope with. This novelty is associated with an aversive event (the electric correction, which has to occur at least once during the training). Depending on the circumstances, the space allowed to the cat can be increased (in the case of cats that are indoors only before the installation of the system) or be restricted (if the cat was free to roam before the installation of the system), which could potentially trigger frustration when it is motivated to access areas outside of the containment area that are rendered inaccessible. Finally, if the cat cannot go outside of its owner's property boundaries, other animals (cats, dogs, foxes) may be able to come in and threaten the cat. It is thus of primary importance to assess the affective state of cats that are exposed to an electronic containment system. In the last decade, the importance of assessing affective state using an 'indicator approach' (Paul et al. 2005) in order to have a more comprehensive view of the animal's welfare has risen (Boissy et al. 2007). It can incorporate the use of behavioural observations (e.g. spontaneous behaviour; Kendall and Ley 2008), behavioural tests (Potter and Mills 2015; Merola et al. 2015), judgment bias (Burman et al. 2008) and physiological (Ramos et al. 2013) indirect measures of affective state. In my study I disregarded indirect physiological measures because they may not covary in the same way, are difficult to rely on because they may be influenced by factors not related to the affective state (for example the season; Mason and Mendl 1993) and difficult to assess non-invasively in a meaningful way relevant to the research question being asked in my study. Spontaneous behaviour in the home is usually and primarily observed by the owner (Kendall and Ley 2008) and can be a useful tool to get an insight into the cat's affective state. Therefore a questionnaire aimed at gathering info on typical behaviours and recent behaviours was designed for the cat owners in my study. The second approach to assessing animal affective state is an adaptation of appraisal theory, developed in humans by Scherer (1999) in which an emotion is elicited in a person by the appraisal of an event, the first level of appraisal being related to the quality of the event (eg "novelty", "intrinsic pleasantness") and the second level to an internal check (eg "coping potential"). In my study, I am specifically interested by the cat's reaction to "novelty", which can be tested using several behavioural tests, such as an "unfamiliar person test", a "novel object test" or a noise test. Finally, a third approach is directly aimed at assessing the animal's judgement bias resulting from its affective state. Animals (including humans Eysenck et al. 1991; Wright and Bower 1992; MacLeod and Byrne 1996; Nygren et al. 1996) are thought to judge the same ambiguous stimulus differently according to their affective state, with animals in a negative affective state judging the stimuli more negatively ('pessimistically') and animals in a positive affective state judging the stimuli more positively ('optimistically'). Therefore I also used a judgment bias test, in order to assess the cat's affective state.

In conclusion, studying the animals' affective state non-physiologically may be done in several ways, using observations of spontaneous behaviour, exposing the animal to the 'challenge' of different behavioural tests and using the cognitive approach (Mendl et al. 2009). In this study, I therefore used these three different approaches in combination to assess the affective state of cats exposed to a specific containment system, studying the reaction of cats to several dimensions of novelty, adapting the judgment bias test for use in cats and using owner-based observations of spontaneous behaviour. Each test is described separately in the methods.

6.2.2 Spontaneous behaviour by mean of an owner questionnaire

Questionnaires and surveys are widely used in research to gather more information about the person's perception of a specific issue related to animals (Toukhsati et al. 2012 on attitudes towards cat containment; Meyer and Forkman 2014 on dog owner relationship). An animal's owner, specifically when the animal is a pet, is most likely to be the person who spends the most time in presence of the animal and interacting with it. Owner's perceptions are thus a useful complementary tool to behavioural testing (Kendall and Ley 2008 in cats). Cat owners are also more experienced and can classify cat vocalisations better than non-cat owners (Nicastro and Owen 2003) as well as being better at classifying the vocalisations of their own cat (Ellis et al. 2015)

The questionnaire was designed to achieve three goals:

- Gather information about owner's perception of their cat's behaviour
- Compare those perceptions to the behavioural tests
- Gather perceptions about potential behavioural changes in the cat

The questionnaire contained demographic items, items on outdoor access, and items about anxiety, stress and the occurrence of specific behaviours (see copy in Appendix 4 for example of a questionnaire). The items relating to specific behaviour were rated using a single measure horizontal visual analogue scale, from 0 to 9 cm (Appukuttan et al. 2014). The owner was asked to rate the typical response frequency for each behaviour and last week frequency for each behaviour, by marking a cross on the scale – See Figure 6.2. Distance in cm was then measured from the 0 point (Never) and reported. For example, if the owner chose the exact middle between Never and very frequent, the reported value would be 4.5.

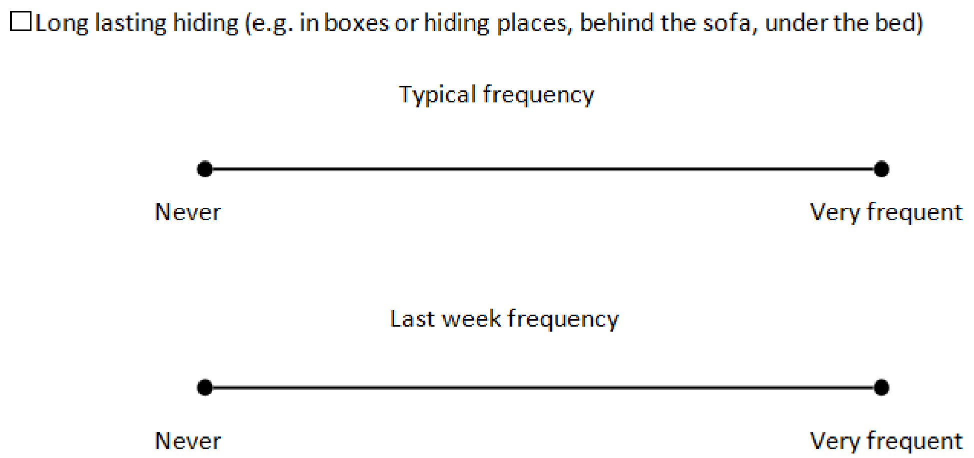

Figure 6.2: Examples of questionnaire’s items, specifically behavioural rating using a Visual Analog Scale of 9 cm from Never to Very Frequent.

The questionnaires were slightly adapted for each group: for example, some items specific to the containment system were removed for the control group. The questionnaires were filled in by the owner after each batch of behavioural tests. The researcher was available to answer any questions and provide examples of behaviours when needed.

6.2.3 Behavioural tests and judgment bias test

A variety of behavioural tests were chosen for assessing cat welfare: an unfamiliar person test, a novel object test and a noise test. A judgment bias test was chosen to assess the cat’s affective state. All tests were performed in the usual environment of the cat in order to avoid any modification of behaviour that would not be caused by the cat’s environment (Rehnberg et al. 2015). Tests were performed over two days; the first three tests that did not necessitate training were carried out on the first day, and the judgment bias test that necessitated training on the second day. The unfamiliar person test had to be performed first in order to minimise the risk of the cat seeing or interacting with the experimenter before the test. Therefore an order was determined that was followed with all the cats. Day one: (1) unfamiliar person test; (2) novel object test; (3) noise test. Day two: (1) the judgment bias test.

6.2.3.1 Unfamiliar person test

Introduction

Studying an animal's response to the approach or presence of a stranger or an unfamiliar person has been done using a variety of tests. Ainsworth et al. (1978) developed a Strange Situation Test (SST or Strange Situation Procedure, SSP) to investigate the attachment and object dependency of the relationship mother-infant. Exact and modified versions of this test have been used to test the attachment between an owner and his animal in dogs (Mariti et al. 2013), cats (Potter and Mills 2015); or a caretaker and wolf pups (Hall et al. 2015). Other tests including an interaction with a stranger are also used: the Stranger Approach Test in cats (McCune 1995) to determine the impact of paternity to behaviour to people, tests including the approach of a stranger friendly or threatening to determine the ability of dogs to discriminate between signals (Vas et al. 2005); the validation of a temperament test in cats (Siegford et al. 2003) and also to elicit vocalisation in cats (comparison between feral cats and house cats; Yeon et al. 2011). The interaction between cat and human seems to increase with the time spent by a familiar human in the home (Mertens 1991), the activity of the human and whether the person is familiar or not (Mertens and Turner 1988), and cats seem to be more active and exploratory in their owner's presence. Taking into account this information, the test was designed to answer three points of interest: how does the cat react to an unfamiliar person when it is alone with the person (primary point, to compare AF cats and C cats)? Does the cat's reaction change depending on the person's activity? What happens in the owner's presence?

Procedure

The study took place in the home setting, the purpose being to assess the time for a cat to approach an unfamiliar person (i.e. a person that has never been encountered or not encountered more than once or twice, with intervals of more than two weeks between encounters) in a familiar environment. The test consisted of four phases lasting up to two minutes per stage. Because of the home setting, the test was designed to minimise disruption and to have only one entrance from the owner. Therefore the four phases were always in the same order. The test took place in a room familiar to the cat, where it was used to having the door closed. If the cat was not used to being in the room with the door closed, a habituation period of two weeks before the test was performed, where the owner would randomly close the door for short period of times until the cat did not react any more to the fact that the door is closed (e.g. not standing in front of the door or meowing in front of the door) Before the test, the unfamiliar person (the visiting researcher) discussed with the owner the best way of calling their particular cat (here represented by the letter X) to trigger a positive response (i.e. cat wanting to interact with the person). The test consisted of four phases (Table 6.1):

Phase	Time	Description
Phase one	Up to two minutes (maximum)	The owner gently introduced the cat into the room by putting the cat on the floor at the room's entrance and closing the door behind it. The unfamiliar person sat more than one metre from the door, hands on her knees, with no direct eye contact with the cat, ignoring the cat until it approached. For all four phases the cat was considered to have approached once it was at less than half a cat's length from the unfamiliar person. The next phase of the test began as soon as the cat had approached the unfamiliar person or once two minutes had elapsed if no approach occurred.
Phase two	Two minutes	A: If the cat had not approached in phase one, then the unfamiliar person extended her hand and called the cat "hello X, come here" every 30 seconds until the cat approached. If the cat still did not approach, the cut-off point was again two minutes and the test moved on to phase three (i.e. the introduction of the owner). If the cat started to interact by looking directly at the person while close and rubbing on the person, the unfamiliar person presented her hand to rub on and stroked the cat, saying "good boy/girl" in a gentle voice. B: If the cat had already approached, the unfamiliar person presented her hand to rub on and stroked the cat if the cat initiated the interaction, saying "good boy/girl" in a gentle way. The words "hello X, come here" were still said every 30 seconds if the cat was not in contact with the unfamiliar person. This lasted for two minutes. The unfamiliar person only interacted with the cat if the cat initiated the interaction, for example, by offering its head or back to stroke, by rubbing on the unfamiliar person, kneading, etc… Each interaction was kept very short, with the unfamiliar person pausing every other second to ensure that the cat still wanted the interaction to continue, by displaying the same initiating behaviours as previously described.

Phase	Time	Description
Phase three	Up to two minutes (maximum)	At the start of this stage the experimenter signalled the owner to come in by saying “you can come in”; and the owner came in to the room, sat in a pre-determined place at least two metres away from the unfamiliar person, perpendicular to the unfamiliar person, with their hands on his/her knees. The unfamiliar person had the same posture. The owner was instructed to ignore their cat and make no eye contact with it during the two remaining stages. The unfamiliar person also made no direct eye contact with the cat, ignoring the cat until it approached. The cat was considered to have approached once it was at less than half a cat’s length from the unfamiliar person, and this for the four phases. The next phase of the test began as soon as the cat had approached the unfamiliar person or once two minutes had elapsed if no approach occurred.
Phase four	Two minutes	A: If the cat had not approached in phase three, then the unfamiliar person extended her hand and called the cat “hello X, come here” every 30 seconds until the cat approached. If the cat still did not approach, the cut-off point was again two minutes. If the cat started to interact by looking directly at the person while close and rubbing on the person, the unfamiliar person presented her hand to rub on and stroked the cat, saying “good boy/girl” in a gentle voice B: If the cat had already approached, the unfamiliar person presented her hand to rub on and stroked the cat if the cat initiated the interaction, saying “good boy/girl” in a gentle way. The words “hello X, come here” were still said every 30 seconds if the cat was not in contact with the unfamiliar person. This lasted for 2 minutes.

Table 6.1: Experimental procedure of the Unfamiliar Person Test.

Predictions

I predicted that neophobic/anxious cats would be slower to approach, and initiate fewer interactions with the unfamiliar person.

6.2.3.2 Novel object test

Introduction

The novel object test explores an animal's response to a novel physical object. This test has been used across a wide range of species (e.g. horses (Winther Christensen et al. 2011), pigs (Guifford et al. 2007), dog and wolves (Moretti et al. 2015), and several species of birds) as a putative measure of anxiety-like behaviour. More specifically, the novel object test has been used to investigate neophobia and its links to social rank (Boogert et al. 2006 in starlings), exploration (Moretti et al. 2015 in wolves and dogs), social housing (being alone or in group; Hillman et al. 2003 in piglets), and risk taking behaviour (Lafaille and Féron 2014 in the mound-building mouse). Usual measures that are recorded include latency to approach the object and interaction (for example touching, pushing) with the object. Time of exposure and habituation to the novel object are measured, as well as the ability for object recognition (Guifford et al. 2007 in pigs; Winther Christensen et al. 2011 in horses). In the cat, studies used the novel object test to investigate individual differences and their relation to social structures in two groups of cats (i.e. one group raised indoors, one group raised outdoors; Durr and Smith 1997), the paternity effect on behaviour towards a novel object (McCune 1995) and social referencing in the cat (Merola et al. 2015). Most studies have shown that the novel object test is a useful tool to detect emotional changes that may be related to stressful situations: for example, piglets housed individually, a condition thought to be stressful for a social species (Hoffman et al. 2012 in horses), displayed signs of alertness and explored the novel object less compared to piglets housed in groups (Hillman et al. 2003). Wolves and dogs explore the novel object more when in a group of conspecifics rather than alone (Moretti et al. 2015). In my study, during the training phase the boundaries not to cross are signalled by means of white flags stuck in the ground at cat level. I used this test to determine if the cat's reaction to a novel object may change after the installation of the containment system.

Procedure

The test took place in a room that was familiar to the cat. The novel object used was one of three different options such that those cats tested on three occasions were always introduced to a different novel object for each test. The objects were selected to be safe for the cat, suitable for a home environment, easy to clean, and unlikely to have been previously encountered by the cats:

- a small marble elephant glued on a 10cm*10cm mirror or
- a small obelisk glued on a 10cm*10cm mirror or
- a resin giraffe glued on a 10cm*10cm mirror

For the AF group which was tested once, the allocation of the objects was pseudo randomised, i.e. 7 cats were presented with the elephant, 7 with the obelisk and 7 with the giraffe. For the C group and the BA group, the same procedure was repeated, and the order of presentation was also pseudo randomised.

The object was placed at 1.5 metres away from the entrance of the room. The owner gently introduced the cat into the room and closed the door, staying outside of the room. The cat (and its potential interaction with the object) was filmed by the experimenter for three minutes from the moment the cat was introduced in the room. The decision to have the experimenter film the cat rather than have a camcorder and a tripod was made because a camcorder on a tripod could not have recorded the cat's behaviour fully, e.g. if the cat went away from the object. Also, the tripod and camcorder themselves could also be considered a novel object by the cat. During the test, other than following the cat with the video camera, the experimenter completely ignored the cat.

Predictions

I predicted that neophobic/anxious cats would approach the novel object less quickly, would have a smaller number of approaches, and fewer contacts with the object. Confident cats will approach the object quickly and investigate the object for a short amount of time then loose interest in the object.

6.2.3.3 Noise test

Introduction

The noise test is a test of suddenness, studying an animal's reaction to a sudden event (visual or auditory event) when the animal is eating. According to the appraisal theory (Scherer 1999), an event can be assessed by the animal according to several criteria, one of them being the suddenness of the event. Suddenness tests are used in a variety of species mostly to investigate fearfulness and emotional reactivity (Lansade et al. 2008; Lansade et al. 2012 in horses; Destrez et al. 2014 in sheep) and also to investigate if predictability of a sudden event changes the emotional response (Greiveldinger et al. 2007). Most of the tests use a combination of a visual and auditory cue, for example the opening of an umbrella which conveys both a very visual and an auditory cue (Lansade et al. 2008; Lansade et al. 2012) or the sudden appearance of a panel near the food area, associated or not to the burst of an air pipe (Greiveldinger et al. 2007; Destrez et al. 2014). The first difficulty of this type of test is to have the animal in a relaxed state before the sudden event occurs. Specifically in social species, it requires a great deal of habituation to being tested alone and to the test area (see habituation procedure in lambs Greiveldinger et al. 2007). In that aspect, my study being in the home environment was at an advantage, the environment being familiar to the test subject. The second difficulty is to trigger the sudden event when the animal is continuously eating and to control for any other potential event that could distract the animal's attention. This was much more of a challenge in the home environment than in an experimental environment when the area had been designed for the purpose of the experiment; nevertheless it could be achieved with preparation. In my study, the test was designed with two purposes: to determine the cat's reaction to a sudden noise while it was eating as a means of assessing anxiety, and to determine if the cats that were exposed to the containment system had a heightened sensitivity to high pitched noises (i.e. noises that have a similar frequency to the warning noise emitted by the collar when the cat approaches within a pre-determined distance of the boundary fence) played out of context (i.e. the cat not being near the boundary). I used an auditory cue only to investigate the AF cats' response to a noise of similar frequency to the warning noise.

Procedure

In my study, a sudden noise was played while the cat was eating its favourite food at its usual feeding place. The choice of the noise was based on consideration of the followings: a noise that had no social content (not a cat hissing or a dog barking or a human yelling) and that would trigger a reaction without being excessively threatening. After testing a variety of potential sounds during a pilot study, the grating sound of a metallic doorway was chosen: a high pitch noise that lasted two seconds, the high pitch making it similar to the warning noise for cats exposed to a containment system.

Two speakers were placed 30cm on one side of the cat's normal food bowl, with the side chosen balanced across cats. The speakers were linked to a computer that was set up as far away as possible from the food bowl. The cat was present during the setting up of the apparatus and was given up to two minutes as a habituation period to adjust to the changes (i.e. presence of the speakers) near to their food bowl. A good quantity of the cat's favourite food was then put into the food bowl (at least enough so that the cat couldn't finish the food prior to the end of the test). When the cat had been eating continuously for at least five seconds, the noise was played. The cat's behaviour was recorded from the start of the test (i.e. prior to food delivery) until 50 seconds after the sudden noise at which point the test ended.

Predictions

I predicted that anxious cats and cats that have a heightened sensitivity to high-pitched noises would stop eating more quickly and for longer; turn their head towards the speaker more often and for longer; and look at the speakers more than non-anxious cats.

6.2.3.4 Judgment bias test

Introduction

The ‘indicator’ approach (Paul et al. 2005) argue that cognitive processes in animals are influenced by emotions (whatever the emotion’s value is, negative or positive) and that those emotions produce “biases” in those cognitive processes. By being able to measure those biases (i.e. attention bias, memory bias and judgment bias), researchers would then be able to measure the animal’s affective state. The focus was to go from theory to a practical way of measuring cognitive biases and to develop a reliable method to apply to animals. The method developed aimed at measuring judgement biases, and the first published study is on rats (Harding et al. 2004) that were trained in a “go/no go” task to press a lever (or not) depending on the frequency of a tone. One frequency preceded the arrival of a food pellet (positive event) and the other frequency preceded a white noise (aversive event). Once trained, the rats were exposed to ambiguous frequencies between the two training frequencies. The hypothesis was that rats in a negative affective state (induced by unpredictable housing) would produce a less positive response (i.e. less presses of the lever) to the ambiguous frequencies than rats in a positive affective state, because they would judge the ambiguous frequencies more ‘pessimistically’ (i.e. have less expectation of the positive event and/or more expectation of the aversive event). These predictions were verified. From this point the experimental paradigm was replicated in numerous studies (see Mendl et al. 2009 for review of most of the studies). At first, one difficulty was to be sure that a positive or a negative affective state has been developed in the subjects in order to replicate the paradigm, difficulty which can be bypassed by using ‘known’ methods (for which there is good evidence of an effect) to induce stress and negative emotion. The cognitive bias test used in this study was a judgement bias test, which is one of the approaches (others include memory and attention bias tests) used to assess the animal’s affective state, or mood (Paul et al. 2005). It has been used in a lot of different species as an approach to assess affective state and hence welfare, mainly to assess the effects of potential ‘affective manipulations’. For example, to see if the experience of environmental enrichment can influence judgement bias (Matheson et al. 2008; Burman et al. 2008, 2009; Brydges et al. 2011) or if the release of restraint, of the end of neglect can produce a positive judgment bias (Doyle et al. 2010a in sheep; Briefer and Eligott 2013 in goats). It is worthy of note that, until very recently, and according to the development of the animal welfare concept, research focused first on studying negative stress, so while methods are available to induce negative affective state leading to states such as anxiety or depression (Porsolt 2000; Destrez et al. 2013a); fewer are available to induce positive affective states (Destrez et al. 2014; Proctor and Carder 2015). The second difficulty is to be sure of what is measured with the paradigm: while it is focused on judgment bias, it is possible that attention bias and memory bias contribute to create the bias in judgement (Mendl et al. 2009).

A spatially based cognitive judgement bias test that was first established in rats (Burman et al. 2008) has since been modified for other species (e.g. dogs (Mendl et al. 2010b), sheep (Destrez et al. 2014)), including for domestic cats kept in a laboratory environment (Tami et al. 2011).The study on cats (Tami et al. 2011) adapted the test procedure established in rats (Burman et al. 2008) but attempted to take into consideration species-specific requirements of the cat. The training in the laboratory setting (Tami et al. 2011) took three to nine days depending on the cat, the criterion being that there was a significant difference between the latencies of the rewarded and unrewarded location. My study took place in the home setting, and the judgment bias test (training and testing) had to be performed in one day. I therefore adapted the test procedure established in dogs using the same criterion (Mendl et al. 2010b) in order to determine if the cats experiencing the containment system were more ‘pessimistic’ than cats not experiencing any type of containment system.

Procedure

The test took place in the home setting in a room familiar to the individual cat being tested. A wire mesh arena of 1.5 metres on 1.5 metres and 25 centimetres high was used to define the training and test area. The entrance was 50 centimetres length. The cat was trained to discriminate between a rewarded location (R) and an unrewarded location (U). At the rewarded location the cat’s favourite food was available in a bowl composed by two feeding bowls stacked together. At the unrewarded location, the food was present, between the two stacked bowls, visible through holes in the top bowl but not available, in order to control for olfactory cues (i.e. all bowls smelled equally of food, but only food in the rewarded location was accessible to the cat). Whatever the location was, the bowl was put at 1.4 metres from the entrance of the arena and the latency to get within 10 centimetres from the bowl with the head directed towards the bowl was recorded, because at that distance the cat was able to see whether the food was available or not (see Figure 6.3).

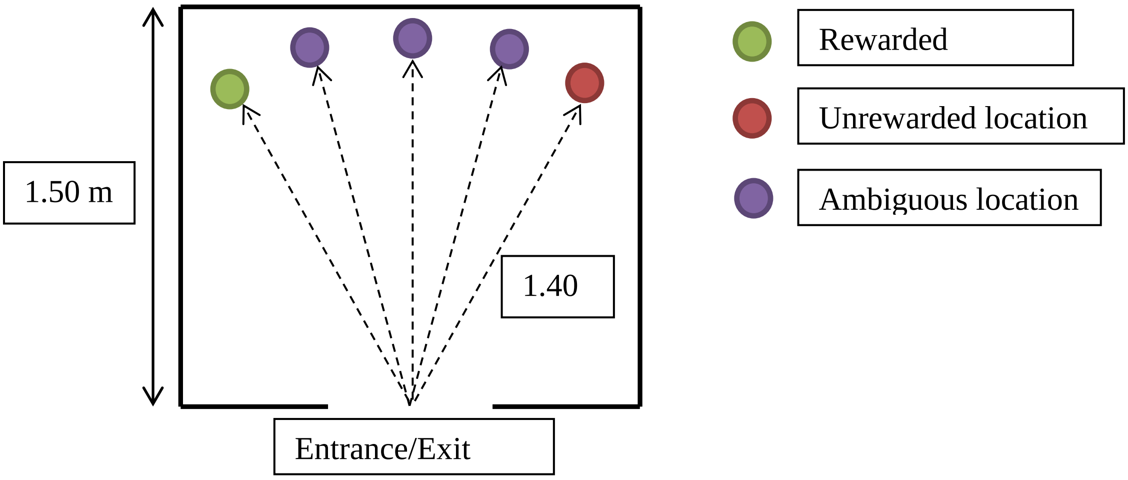

Figure 6.3: Judgment bias test arena and example of locations of the food bowl.

Given previous published issues with the length of time to complete the training for cats in this sort of test (Tami et al. 2011), the motivation for the cats to complete the test was expected to be a major difficulty. The owners were therefore asked not to feed their cat at least three hours before the beginning of the test and to determine what their cat's favourite food or treat was so that this could be used as the test food. After a pilot study with four cats, the training and testing phase were carefully designed to maintain this motivation and were adapted to the cat's reactions, with a certain number of consistencies:

- The training phase always began with at least three R trials, to motivate the cat to explore the bowls.
- No more than three U trials were given in succession in order to keep the cat's motivation.
- The testing phase began immediately after the cat reached the training criterion, in accordance with Mendl et al (2010b) and in order to maintain the cat's motivation, the pilot study having showed that if a period of rest is given the cat was not motivated to resume testing.
- The testing phase contains more R trials than U trials, e.g. NR R M R NU U
- The ambiguous locations were presented only once to avoid potential problems due to immediate repeated testing (Doyle et al 2010b).

The training procedure was divided in sessions of six trials each, and the sessions were performed one after the other with up to 30 seconds breaks between each session, the pilot study having showed that longer breaks resulted in a decrease in the cat's motivation. The cat was gently put near the arena's entrance by the researcher, who did put the bowl at the determined location, then timed the latency to approach the bowl with a stopwatch, from the moment the cat's front paw was inside the arena to the moment the cat reached the bowl or was within 10 centimetre of the bowl. If the cat failed to go to a location within 15 seconds, then that particular trial was ended. The training phase lasted until the cat reached the success criterion or refused to continue the test. The success criterion was that for six consecutive trials involving three R and three U trials, the cat would consistently run faster to the R location than to the U location (Mendl et al. 2010b). For half the cats the rewarded location was on the left side, and for the other half the rewarded location was on the right side.

The testing phase, beginning immediately after the cat had reached the criterion, exposed the cat to three ambiguous locations of the food bowl: the near rewarded location (NR), the middle location (M) and the near unrewarded location (NU). The test consisted of four to seven trials (depending on the cat's motivation), where the ambiguous locations were presented in a random order interspersed with training trials. Each ambiguous location was presented just once (Doyle et al. 2010b).

Predictions

Regarding the containment system, I predicted that if cats were more anxious as a result of containment, then I would expect them (AF cats) to run slower to the ambiguous locations (i.e. be more 'pessimistic') than control cats (C cats).

6.2.4 Video analysis

Video recordings from the Unfamiliar Person Test, the Novel Object test and the Noise Test were analysed according to the following procedure. First, a random sample of 10% of the videos were watched in order to identify the range of behaviours that were likely to be present. Then a specific ethogram was designed for each test, with the behavioural definitions adapted from Stanton et al. (2015). The ethograms categorized the location, locomotion, posture behaviours, and the behaviours specific to the test (i.e. interaction with the object, interaction with the unfamiliar person, and interaction with the owner). Behaviours that might indicate arousal or a negative affective state (i.e. anxiety, stress) were also recorded (e.g. lip licking, yawning, head shaking, skin twitching), as well as any kind of vocalisation the cat may produce (e.g. meowing, purring, hissing) (see copy of the ethograms in Appendix 3). The videos were coded with Noldus Observer 10.5, and then the data were exported and entered for analysis with SPSS version 22. The video were coded with continuous sampling, and yielded frequencies, durations and latencies of state behaviours, and frequencies of point behaviours.

6.2.5 Data analysis

Here is described only the general procedure of data analysis, the specific procedure for each test being detailed in Chapter 8.

For the unfamiliar person test, the novel object test and the noise test, the data was entered into an Excel spreadsheet after video coding, entering only behaviours of interest (ie related to the object, or interaction with a person, etc). For the questionnaire and the judgment bias test, the data was entered directly. All behaviours performed by less than 20% of the cats were removed from analysis.

Graphs were plotted in order to visualise the data, using histograms to plot mean and standard error, then using boxplots to visualise the median, interquartile range and outliers. Identifying what cat is flagged at an outlier for each behaviour has for purpose to determine if there is a pattern, and if one or several cats would consistently (i.e. for a majority of behaviours) be flagged as an outlier. It would show if one cat consistently differs from the average of its group. For the BA group, variable values were presented in tables for the four cats (see Chapter 7). For the AF versus C group, the detailed statistics analysis is presented in Chapter 8.

6.3 Conclusion

In order to assess the affective state of cats exposed to an electronic containment system, I designed an owner questionnaire aimed at specific typical and recent behaviours, adapted three behavioural tests for use in the cat and for my purpose, and adapted a judgment bias test for use in the home environment in the cat. These tests were used in small case series for cats that were tested before and after the installation of the system (Chapter 7) and to compare cats that were exposed to the system for more than 12 months to control cats (Chapter 8).

Chapter Seven

Cats tested before and after the containment system's installation

This chapter presents a small case series looking at the potential impact of an electronic containment system on the affective state of cats, focusing on potential differences in behaviour before the installation of the system, 10 to 15 days after the system's installation (i.e. the short term effect) and 10 to 14 weeks after the system's installation (i.e. the longer term effect).

7.1 Introduction

As stated previously (Chapter 1), an electronic containment system is triggered by the animal's own behaviour, giving it a measure of control over the possible occurrence of an aversive event (Basset and Buchanan Smith 2007; Greiveldinger et al. 2007). Recent research on electronic containment systems has been carried out in cattle (Lee et al. 2009; Umstatter et al. 2015) and sheep (Jouven et al. 2012), and found that cattle were able to associate an auditory cue and the electric correction (Lee et al. 2009) and that different systems of virtual fences are efficient in controlling the grazing area of sheep and cattle (Jouven et al. 2012; Umstatter et al. 2015). Thus the focus to date has been mainly on the efficacy of the systems. A comparison of the effect of electric fences versus electronic containment systems has also been made (Markus et al. 2014). This found that the heifers fitted with the electronic collar avoided the "test" area (area designed to be avoided) for four days after the end of the experiment, compared to heifers that were subjected only to visible electric fences, the authors suggesting that heifers fitted with the electronic collar associated the aversive stimulus with the spatial location of the exclusion area (Markus et al. 2014). The welfare implications of the electronic containment system have not been studied at length. In early studies (Tibbs et al. 1995; Tiedemann et al. 1999) the weight of animals (heifers and steers) was monitored but the results were not considered conclusive. Steers in the treatment group lost weight in Tiedemann et al. (1999), heifers and steers in the treatment groups in Tibbs et al. (1995) gained less weight than control group. In the first of these studies, the authors attributed this effect to both the training taking additional time and interfering with grazing duration, and/or to stress during the testing. However, after a few days the steers seemed to habituate to the system and weighing them over a longer time could have yielded different results. In the second study, the groups of heifers and steers in the treatment group might have gained less than the control group because the control group had access to the riparian areas (Tibbs et al. 1995). In recent studies (Lee et al. 2009; Jouven et al. 2012) behaviour measurements were performed but the focus was on avoidance behaviours (for example "turn", "back up") and no tests were performed to assess the affective state of the animals. The only measurement of behaviours not focused on avoidance is reported in a study on cattle (Umstatter et al. 2015) stating that "No changes in general activity or lying behavior were found", suggesting that the general behaviour of the cows was not affected during the time of the experiment. This is valuable information but needs further exploration to draw firm conclusions about the welfare impact of an electronic containment system. Focusing on the cat, no peer-reviewed research has been published on the way cats would respond to an electronic containment system (CAWC report, Mills et al. 2012).

Case studies are widely used in veterinary medicine to make initial reports of observations of wider interest to the profession, for example, the possible association between diseases or the postulation of risk factors for a specific disease (Malik et al. 2006; Case et al. 2007). Although they provide low level evidence in the overall scheme of evidence-based practice, the details they provide may be useful in individual situations (Mantzoukas 2008) and they help to generate hypotheses for subsequent higher evidence studies, for example a case control study with a larger sample (Burns et al. 2011).

I report here on the response of a small number of cats (convenience sample) before and after the installation of a containment system to a range of behavioural and cognitive tests, in conjunction with gathering information on the owner's perceptions of their own cats' behaviour. The purpose of the study was to get an initial insight into the short and longer term response of the cat to the installation of an electronic containment system (i.e. "the system" in the rest of the manuscript). This also allowed the piloting of methods that could be used in a larger study.

7.2 Methods

7.2.1 Subjects

Four cats living in three households were recruited. Three cats were male (Indi, Benji and Jazz), one cat (Hilda) was female and all cats were neutered. All cats lived in multi-cat households. Indi and Benji lived together, Hilda lived with three other cats that were not a part of the study, and Jazz lived with one other cat. Demographics are presented in Table 7.1. The four cats belonged to two groups: Three cats were indoors only cats (Indi, Benji, Hilda) before the installation of the containment system, and one cat (Jazz) was free to roam, the containment system being installed with the sole purpose of preventing this cat from accessing a neighbour's property and attacking the neighbour's cat, i.e. the neighbour’s property was enclosed by the system rather than the conventional use of the system to contain the owner’s cat within the confines of their own property.

Cat name	Cat sex (all neutered)	Cat age (in years)	Total number of cats in the household
Indi	Male	3	2
Benji	Male	3	2
Jazz	Male	3	2
Hilda	Female	14	4

Table 7.1: Demographics of cats included in the study.

7.2.2 Rationale about reduced and increased welfare

I hypothesised that cats that are generally more anxious would consider novelty with caution. Therefore, anxious cats would interact less with an unfamiliar person, which can be translated with less gaze towards the unfamiliar person, taking into account that the cat is in a familiar environment and can be away from the person, less contact with the unfamiliar person, more display of anxiety/conflict related behaviours such as lip licking, self grooming (Podberscek et al. 1991; Van den Bos 1998; Schwartz 2002). I also hypothesised that anxious cats would meow more as vocalisations can be an indicator of stress. Regarding the novel object test, I hypothesised that anxious cats would approach less and interact less with the novel object, keeping their distances with a potential threat; specifically if they were to generalise the training about the containment system (which uses flags to render the boundary visible). Regarding the noise test, cats reactive to a sudden noise would turn their head in the noise direction, look at the speakers and have their ears moving in order to stay on alert for potential other noises.

7.2.3 Time line for testing

The test procedures have been described in Chapter 6 and the time line (including part of the project that were not performed by the author, such as camera recording, collar wearing and passive avoidance test) is presented in Figure 7.1

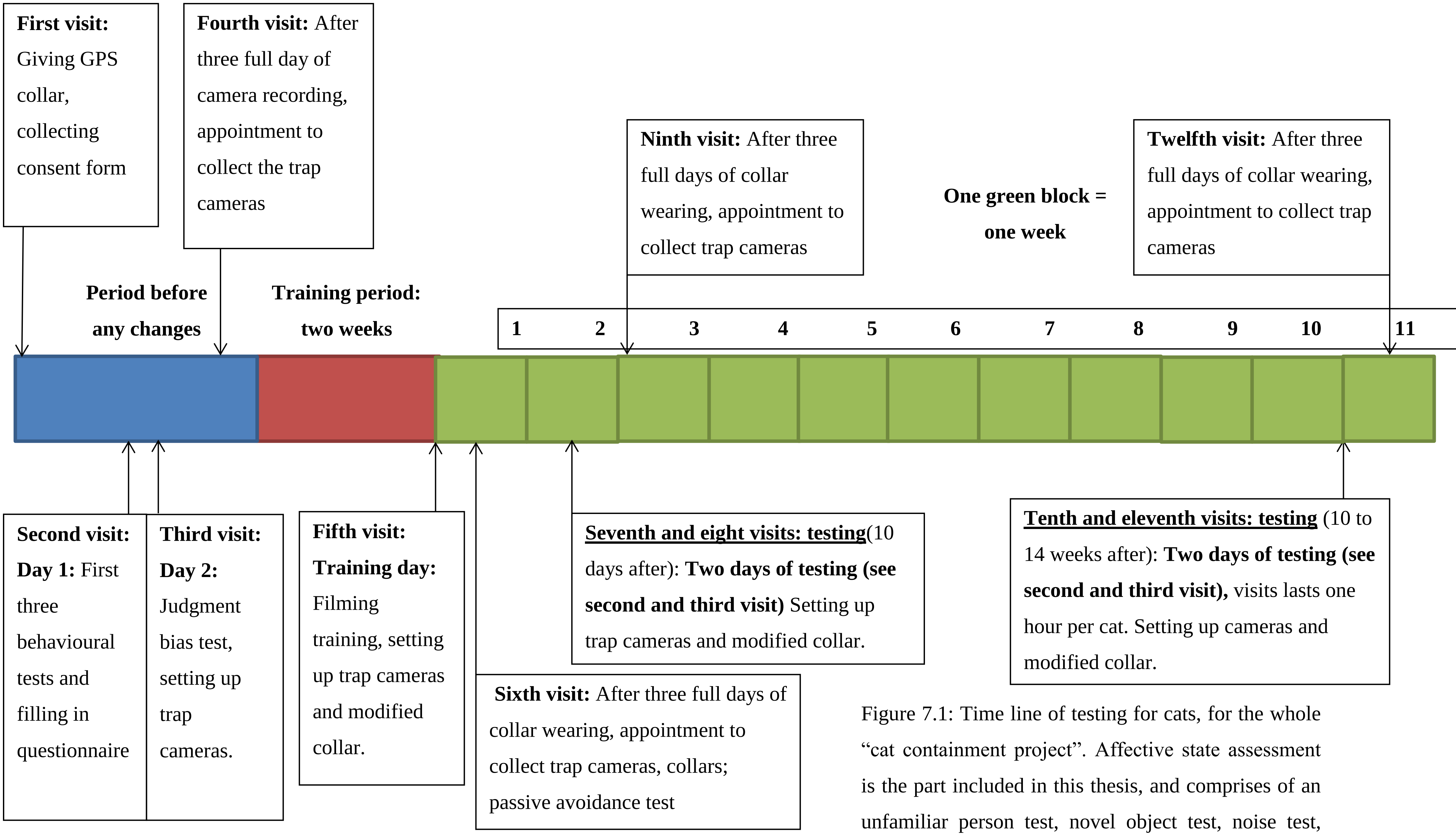

Figure 7.1: Time line of testing for cats, for the whole “cat containment project”. Affective state assessment is the part included in this thesis, and comprises of an unfamiliar person test, novel object test, noise test, judgment bias test and owner questionnaire

7.3 Results

The results are presented per test, in tables that provide summary values for each cat and each variable. In order to highlight potential effects, I calculated the standard deviation for the population at baseline, and highlighted **in bold** all values that are equal or more than one standard deviation away from the baseline value, and in the direction of potential **reduced** welfare. I*n red italics* are identified values that are in the direction of potential *increased* welfare. Missing values are represented by an empty box. The short term testing is the testing 10 to 15 days after installation, and the longer term testing 10 to 14 weeks after the system's installation.

7.3.1 Unfamiliar person test

7.3.1.1 Phase One: unfamiliar person alone with cat, passive

Cat Name	Variable	Baseline	Short term	Longer term
BENJI	Gaze Towards Stranger Duration	0.857	**0.264**	1.000
	Gaze Towards Stranger Frequency	0.298	0.287	*0.641*
	Tail Up Duration		0.000	
	Tail Up Frequency		0.000	
	Meowing Frequency	0.084	*0.000*	*0.000*
INDI	Gaze Towards Stranger Duration	0.276	0.141	0.000
	Gaze Towards Stranger Frequency	0.187	0.094	0.000
	Tail Up Duration	0.219	0.000	*1.000*
	Tail Up Frequency	0.238	0.000	*12.500*
	Meowing Frequency	0.062	0.000	0.119
HILDA	Gaze Towards Stranger Duration	0.386	0.132	**0.000**
	Gaze Towards Stranger Frequency	0.142	0.102	0.000
	Tail Up Duration	0.000	0.000	0.361
	Tail Up Frequency	0.000	0.000	0.137
	Meowing Frequency	0.000	**0.210**	0.000
JAZZ	Gaze Towards Stranger Duration	0.947	**0.245**	
	Gaze Towards Stranger Frequency	0.658	0.472	
	Tail Up Duration	1.000	**0.481**	
	Tail Up Frequency	1.316	**0.236**	
	Meowing Frequency	0.216	*0.000*	

Table 7.2: Variables' recorded for each cat for Phase one. Values that are equal or more than one standard deviation away from the baseline value and in the direction of potential reduced welfare are highlighted in bold. Values equal or more than one standard deviation away from the baseline value and in the direction of potential increased welfare are highlighted in red italics. Gaze Towards Stranger Duration (SD=0.290); Gaze Towards Stranger Frequency (SD=0.203); Tail Up Duration (SD=0.429); Tail Up Frequency (SD=0.572); Meowing Frequency (SD=0.079).

Only Jazz, the cat being excluded from the neighbour's garden by the system, presented a degree of consistency in a potential decrease in positive behaviours towards the stranger during the short term testing with this test. The three other cats did not show consistent changes indicating a potential decrease in welfare, and the individual results probably reflect random variation. Benji showed an increase in gaze toward the stranger and decrease in meowing during the long term testing, and Indi showed an increase in greeting behaviour during the long term testing, all changes potentially consistent with improved welfare.

7.3.1.2 Phase Two: unfamiliar person alone with cat, active

Cat	Variable	Baseline	Short term	Longer term
BENJI	Gaze Towards Stranger Duration	0.149	0.110	0.129
	Gaze Towards Stranger Frequency	0.094	0.097	0.078
	Sniffing Stranger Duration	0.312	**0.000**	**0.010**
	Sniffing Stranger Frequency	0.094	**0.000**	**0.012**
	Rubbing Stranger Duration	0.000	0.000	0.000
	Rubbing Stranger Frequency	0.000	0.000	0.000
	Initiating Interaction with Stranger F.	0.000	0.000	0.000
	Tail Up Duration	0.573	**0.000**	**0.086**
	Head Shaking Frequency	0.000	0.000	0.000
	Lip Licking Frequency	0.000	**0.030**	0.000
	Meowing Frequency	0.078	*0.000*	*0.000*
INDI	Gaze Towards Stranger Duration	0.201	0.279	0.094
	Gaze Towards Stranger Frequency	0.064	0.088	0.070
	Sniffing Stranger Duration	0.010	0.000	0.009
	Sniffing Stranger Frequency	0.028	0.000	0.019
	Rubbing Stranger Duration	0.000	0.000	0.005
	Rubbing Stranger Frequency	0.000	0.000	0.019
	Initiating Interaction with Stranger F.	0.000	0.000	0.019
	Tail Up Duration	0.718	**0.386**	0.689
	Head Shaking Frequency	0.000	0.000	0.000
	Lip Licking Frequency	0.000	**0.039**	0.000
	Meowing Frequency	0.071	0.047	**0.144**
HILDA	Gaze Towards Stranger Duration	0.251	0.236	0.203
	Gaze Towards Stranger Frequency	0.182	0.150	0.190
	Sniffing Stranger Duration	0.003	0.005	0.000
	Sniffing Stranger Frequency	0.009	0.008	0.000
	Rubbing Stranger Duration	0.071	**0.027**	0.057
	Rubbing Stranger Frequency	0.087	0.109	0.165
	Initiating Interaction with Stranger F.	0.035	0.042	0.017
	Tail Up Duration	0.384	*0.812*	*0.822*
	Head Shaking Frequency	0.009	0.008	0.008
	Lip Licking Frequency	0.009	*0.000*	*0.000*
	Meowing Frequency	0.034	*0.000*	*0.000*

Cat	Variable	Baseline	Short term	Longer term
JAZZ	Gaze Towards Stranger Duration	0.472	**0.140**	
	Gaze Towards Stranger Frequency	0.092	0.080	
	Sniffing Stranger Duration	0.067	0.023	
	Sniffing Stranger Frequency	0.042	**0.010**	
	Rubbing Stranger Duration	0.047	0.051	
	Rubbing Stranger Frequency	0.083	0.069	
	Initiating Interaction with Stranger F.	0.050	0.030	
	Tail Up Duration	0.641	0.579	
	Head Shaking Frequency	0.008	*0.000*	
	Lip Licking Frequency	0.000	0.000	
	Meowing Frequency	0.008	0.000	

Table 7.3: Variables recorded for each cat for Phase two. Values that are equal or more than one standard deviation away from the baseline value and in the direction of potential reduced welfare are highlighted in bold. Values equal or more than one standard deviation away from the baseline value and in the direction of potential increased welfare are highlighted in red italics. Gaze Towards Stranger Duration (SD=0.123); Gaze Towards Stranger Frequency (SD=0.045); Sniffing Stranger Duration (SD=0.126); Sniffing Stranger Frequency (SD=0.031); Rubbing Stranger Duration (SD=0.031); Rubbing Stranger Frequency (SD=0.043); Initiating Interaction with Stranger Frequency (SD=0.022); Tail Up Duration (SD=0.124); Head Shaking Frequency (SD=0.004); Lip Licking Frequency (SD=0.004); Meowing Frequency (SD=0.028).

Benji presented, in the short term and longer term tests, a decrease in sniffing the unfamiliar person and in greeting behaviour, with the potential anxiety/conflict like behaviour “lip licking” increasing in the short term testing, by contrast meowing decreased both in the short and longer term testing. Indi presented in the short term test with an increase in “lip licking” and a decrease in greeting behaviour. In the longer term test, Indi presented with an increase in meowing. Hilda presented a decrease in potential anxiety/conflict like behaviour in both the short term and longer term tests. Jazz did not present consistent changes.

7.3.1.3 Phase Three: owner and unfamiliar person present, passive

Cat	Variable	Baseline	Short Term	Longer Term
BENJI	Gaze Towards Stranger Duration	0.000	0.000	
	Gaze Towards Stranger Frequency	0.000	0.000	
	Tail Up Duration	0.150	0.000	0.000
	Tail Up Frequency	0.107	**0.000**	**0.000**
	Meowing Frequency	0.020	0.000	0.000
	Gaze Towards Owner Duration	0.438	**0.100**	
	Gaze Towards Owner Frequency	0.127	0.093	
	Sniffing Owner Duration	0.000	*0.183*	0.000
	Sniffing Owner Frequency	0.000	*0.087*	0.000
INDI	Gaze Towards Stranger Duration	0.000	0.000	0.011
	Gaze Towards Stranger Frequency	0.000	0.000	0.009
	Tail Up Duration	0.000	0.000	0.034
	Tail Up Frequency	0.000	0.000	0.009
	Meowing Frequency	0.097	0.025	0.096
	Gaze Towards Owner Duration	0.000	0.074	0.022
	Gaze Towards Owner Frequency	0.000	*0.143*	0.009
	Sniffing Owner Duration	0.000	0.000	0.000
	Sniffing Owner Frequency	0.000	0.000	0.000
HILDA	Gaze Towards Stranger Duration	0.081	0.132	0.056
	Gaze Towards Stranger Frequency	0.051	0.072	0.056
	Tail Up Duration	0.860	0.935	1.000
	Tail Up Frequency	0.031	0.047	0.056
	Meowing Frequency	0.000	0.000	0.000
	Gaze Towards Owner Duration	0.305	0.229	0.241
	Gaze Towards Owner Frequency	0.077	0.101	*0.169*
	Sniffing Owner Duration	0.024	0.033	**0.000**
	Sniffing Owner Frequency	0.025	*0.042*	**0.000**
JAZZ	Gaze Towards Stranger Duration	0.169	*0.245*	
	Gaze Towards Stranger Frequency	0.052	*0.161*	
	Tail Up Duration	0.481	*1.000*	
	Tail Up Frequency	0.077	*0.658*	
	Meowing Frequency	0.181	0.122	
	Gaze Towards Owner Duration	0.022	0.077	
	Gaze Towards Owner Frequency	0.026	*0.161*	
	Sniffing Owner Duration	0.000	0.000	
	Sniffing Owner Frequency	0.000	0.000	

Table 7.4: Variables recorded for each cat for Phase three. Values that values that are equal or more than one standard deviation away from the baseline value, and in the direction of potential reduced welfare are highlighted in bold. Values equal or more than one standard deviation away from the baseline value and in the direction of potential increased welfare are highlighted in red italics. Gaze Towards Stranger Duration (SD=0.070); Gaze Towards Stranger Frequency (SD=0.026); Tail Up Duration (SD=0.331); Tail Up Frequency (SD=0.041); Meowing Frequency (SD=0.071); Gaze Towards Owner Duration (SD=0.187); Gaze Towards Owner Frequency (SD=0.050); Sniffing Owner Duration (SD=0.010); Sniffing Owner Frequency (SD=0.011)

Benji presented a decrease in greeting behaviour over time and a mild decrease in Gaze Towards Owner Duration, but sniffed the owner more during the short rem test. Hilda sniffed her owner less in the long term test. Jazz presented a consistent increase in greeting behaviour and gazes towards the stranger and owner. Indi did not present any consistent changes.

7.3.1.4 Phase Four: owner passive, unfamiliar person active

Cat	Variable	Baseline	Short Term	Longer Term
BENJI	Gaze Towards Stranger Duration	0.117		*0.828*
	Gaze Towards Stranger Frequency	0.082		*0.165*
	Rubbing Stranger Duration	0.000		0.000
	Rubbing Stranger Frequency	0.000		0.000
	Initiating Interaction with Stranger	0.000		0.000
	Tail Up Duration	0.000		0.000
	Self-Grooming Duration	0.142		*0.000*
	Meowing Frequency	0.099	*0.000*	*0.000*
	Gaze Towards Owner Duration	0.000		0.000
	Gaze Towards Owner Frequency	0.000		0.000
	Initiating Interaction with Owner F.	0.000		0.000
INDI	Gaze Towards Stranger Duration	0.129	**0.000**	0.126
	Gaze Towards Stranger Frequency	0.060	**0.000**	*0.102*
	Rubbing Stranger Duration	0.000	0.000	0.000
	Rubbing Stranger Frequency	0.000	0.000	0.000
	Initiating Interaction with Stranger	0.000	0.000	0.000
	Tail Up Duration	0.465	0.578	0.619
	Self-Grooming Duration	0.000	0.000	0.000
	Meowing Frequency	0.100	*0.000*	*0.025*
	Gaze Towards Owner Duration	0.079	**0.000**	**0.000**
	Gaze Towards Owner Frequency	0.119	**0.000**	**0.000**
	Initiating Interaction with Owner F.	0.068	**0.000**	0.042
HILDA	Gaze Towards Stranger Duration	0.168	**0.079**	**0.096**
	Gaze Towards Stranger Frequency	0.141	**0.091**	**0.104**
	Rubbing Stranger Duration	0.086	**0.023**	0.075
	Rubbing Stranger Frequency	0.116	**0.067**	0.146
	Initiating Interaction with Stranger	0.042	**0.025**	**0.009**
	Tail Up Duration	0.347	0.446	*0.735*
	Self-Grooming Duration	0.000	0.052	0.000
	Meowing Frequency	0.000	0.000	0.000
	Gaze Towards Owner Duration	0.076	**0.005**	0.062
	Gaze Towards Owner Frequency	0.033	0.008	0.017
	Initiating Interaction with Owner F.	0.000	0.000	0.009

Cat	Variable	Baseline	Short Term	Longer Term
JAZZ	Gaze Towards Stranger Duration	0.171	**0.137**	
	Gaze Towards Stranger Frequency	0.087	0.083	
	Rubbing Stranger Duration	0.033	*0.093*	
	Rubbing Stranger Frequency	0.034	*0.091*	
	Initiating Interaction with Stranger	0.009	0.025	
	Tail Up Duration	0.222	*0.446*	
	Self-Grooming Duration	0.009	0.000	
	Meowing Frequency	0.051	*0.000*	
	Gaze Towards Owner Duration	0.011	*0.058*	
	Gaze Towards Owner Frequency	0.026	0.025	
	Initiating Interaction with Owner F.	0.000	0.000	

Table 7.5: Variables recorded for each cat for Phase four. Values that are equal or more than one standard deviation away from the baseline value and in the direction of potential reduced welfare are highlighted in bold. Values equal or more than one standard deviation away from the baseline value and in the direction of potential increased welfare are highlighted in red italics. Gaze Towards Stranger Duration (SD=0.024); Gaze Towards Stranger Frequency (SD=0.030); Rubbing Stranger Duration (SD=0.035); Rubbing Stranger Frequency (0.048); Initiating Interaction with Stranger Frequency (SD=0.017); Tail Up Duration (SD=0.172); Self-Grooming Duration (SD=0.061); Meowing Frequency (SD=0.041); Gaze Towards Owner Duration (SD=0.036); Gaze Towards Owner Frequency (SD=0.045); Initiating Interaction with Owner Frequency (SD=0.029).

For Benji, all changes in this test were consistent with a potential increase in welfare with more gaze towards the stranger and a decrease in self-grooming and meowing in the longer term testing. Indi presented a decrease in welfare in the short term testing (looking less and interacting less with owner and stranger) and just a mild decrease in interaction with owner in the longer term testing.

Hilda interacted less with the stranger and the owner but positive behaviour (except for greeting behaviour in the longer term testing) and behaviour linked to potential anxiety/conflict did not change. Jazz presented with a large increase in greeting behaviour, gaze and interaction towards the stranger and the owner in the longer term testing.

7.3.2 Novel object test

Regarding the novel object test, highlighted **in bold** are values that are equal or more than one standard deviation away from the baseline value, and in the direction of potential **reduced** welfare, and *in red italics* values that are of a similar magnitude and consistent with a potential in *increased* welfare and an *increased interest in the novel object.*

Cat name	Variables	Baseline	Short Term	Longer Term
BENJI	Near Object Duration	4.8	*49.6*	11.68
	Gaze Towards Object Duration	8.32	13.16	5.44
	Gaze Towards Experimenter Duration	4.24	8	7
	Gaze Towards Door Duration	7.16	10.44	3.6
	Tail Up Duration	6.68	4.12	4.52
	Sniffing Object Duration	4.28	6.84	2.88
	Self-Grooming Duration	3.96	**75.96**	0
	Near Object Frequency	1	1	1
	Gaze Towards Object Frequency	5	**3**	4
	Gaze Towards Experimenter Frequency	3	6	7
	Gaze Towards Door Frequency	6	5	4
	Tail Up Frequency	3	**1**	2
	Sniffing Object Frequency	1	*3*	1
	Self-Grooming Frequency	1	**9**	0
	Lip Licking Frequency	5	**10**	3
	Head Shaking Frequency	1	*0*	*0*
	Meowing Frequency	5	*0*	*0*
	Ears Towards Object Frequency	0	0	*2*
INDI	Near Object Duration	19.16	15.76	*117.12*
	Gaze Towards Object Duration	15.36	11.56	*47.44*
	Gaze Towards Experimenter Duration	5.12	4.36	1.16
	Gaze Towards Door Duration	42.88	27.72	49.52
	Tail Up Duration	4.36	*23.2*	9.72
	Sniffing Object Duration	11.24	**4.96**	*23.16*
	Self-Grooming Duration	15.16	23.29	0
	Near Object Frequency	2	*3*	**1**
	Gaze Towards Object Frequency	4	5	*13*
	Gaze Towards Experimenter Frequency	2	3	1
	Gaze Towards Door Frequency	9	6	6
	Tail Up Frequency	1	*5*	2
	Sniffing Object Frequency	3	4	*10*
	Self-Grooming Frequency	4	4	*0*
	Lip Licking Frequency	1	4	1
	Head Shaking Frequency	1	1	*0*
	Meowing Frequency	3	*0*	3
	Ears Towards Object Frequency	0	0	*2*

Cat	Variables	Baseline	Short Term	Longer Term
HILDA	Near Object Duration	0	4.16	*8.52*
	Gaze Towards Object Duration	0.24	4.16	*6.92*
	Gaze Towards Experimenter Duration	4.68	8.48	39.44
	Gaze Towards Door Duration	54.72	5.6	16.92
	Tail Up Duration	0	5.16	0
	Sniffing Object Duration	0	0.68	2.4
	Self-Grooming Duration	66.36	73.48	*2.4*
	Near Object Frequency	0	*1*	*2*
	Gaze Towards Object Frequency	1	*4*	*4*
	Gaze Towards Experimenter Frequency	2	3	5
	Gaze Towards Door Frequency	2	3	5
	Tail Up Frequency	0	1	0
	Sniffing Object Frequency	0	1	*2*
	Self-Grooming Frequency	5	7	*1*
	Lip Licking Frequency	8	**14**	*3*
	Head Shaking Frequency	0	**1**	**1**
	Meowing Frequency	10	*0*	*0*
	Ears Towards Object Frequency	0	0	*1*
JAZZ	Near Object Duration	1	*162.89*	0
	Gaze Towards Object Duration	5	*20.64*	5.48
	Gaze Towards Experimenter Duration	10.2	4.24	4.92
	Gaze Towards Door Duration	5.84	31.4	53.24
	Tail Up Duration	17.44	**5.8**	14.52
	Sniffing Object Duration	0	*12.72*	0
	Self-Grooming Duration	0	0	12.04
	Near Object Frequency	1	1	0
	Gaze Towards Object Frequency	2	*10*	3
	Gaze Towards Experimenter Frequency	5	7	8
	Gaze Towards Door Frequency	3	3	7
	Tail Up Frequency	2	2	*4*
	Sniffing Object Frequency	0	*7*	0
	Self-Grooming Frequency	0	0	**5**
	Lip Licking Frequency	0	**6**	2
	Head Shaking Frequency	0	0	**1**
	Meowing Frequency	4	3	6
	Ears Towards Object Frequency	1	1	*2*

Table 7.6: Variables recorded for each cat for the novel object test. Highlighted in bold are values that are equal or more than one standard deviation away from the baseline value, and in the direction of potential reduced welfare, and in red italics values that are equal or more than one standard deviation away from the baseline value and show an increased interest in the novel object and a potential in increased welfare. Near Object Duration (SD=7.67); Gaze Towards Object Duration (SD=5.50); Gaze Towards Experimenter Duration (SD=2.41); Gaze Towards Door Duration (SD=21.57); Tail Up Duration (SD=6.42); Sniffing Object Duration (SD=4.59); Self-Grooming Duration (SD=26.56);

Near Object Frequency (SD=0.71); Gaze Towards Experimenter Frequency (SD=1.58); Gaze Towards Experimenter Frequency (SD=1.22); Gaze Towards Door Frequency (SD=2.74); Tail Up Frequency (SD=1.12); Sniffing Object Frequency (SD=1.22); Self-Grooming Frequency (SD=2.06); Lip Licking Frequency (SD=3.20); Head Shaking Frequency (SD=0.5); Meowing Frequency (SD=2.69); Ears Towards Object Frequency (SD=0.43).

There are seven variables linked to the interaction with object (eg NOD NOF GTOD GTOF SOD SOF ETOF), and three variables (LLF SGD SGF) linked to potential anxiety/conflict-like behaviour. Gaze towards the experimenter and Gaze towards the door show the cat's reaction to the situation, and are not included in the values interpreted for an increase or decrease in welfare.

7.3.2.1 Short term testing

Benji showed an increase in time near the object and in potential anxiety/conflict like behaviours and a decrease in greeting behaviour. Indi did not show any consistent changes, Hilda showed an increase in "Lip licking" and Jazz showed a very consistent and strong interest in the object associated with an increase in "Lip licking" and a decrease in greeting behaviour.

7.3.2.2 Longer term testing

For the longer term testing, there is little consistency between cats: two cats (Indi and Hilda) show an increase in most variables' values linked to the object; while Benji and Jazz show inconsistent and mild increase in one to three variables linked to the object. Again, regarding variables linked to potential anxiety/conflict-like and irritation behaviours, there was a consistent decrease in durations and frequencies for all cats except Jazz, but the changes appear small.

7.3.3 Noise test

For the noise test, highlighted **in bold** are values that are equal or more than one standard deviation away from the baseline value, and in the direction of potential **reduced** welfare, and *in red italics* values that are of a similar magnitude and consistent with a potential in *increased* welfare.

Cat	Variable	Baseline	Short Term	Longer Term
BENJI	Non Feeding Duration	8.65	0	*5.52*
	Head Towards Speaker Duration	3.76	*0*	2.72
	Ears Stationary Duration	42.37	*48.71*	*46.19*
	Non Feeding Frequency	3	*0*	3
	Head Towards Speaker Frequency	3	*0*	3
	Ears Towards Speaker Frequency	2	*0*	**4**
	Ears Not Towards Speaker Freq.	2	1	2
	Lip Licking Frequency	3	*0*	**5**
	Non Feeding Latency	30.28	50	**7.36**
	Head Towards Speaker Latency	30.24	50	**7.44**
INDI	Non Feeding Duration	5	0	*3.28*
	Head Towards Speaker Duration	4.16	*0*	2.8
	Ears Stationary Duration	42.61	*49.31*	*48.03*
	Non Feeding Frequency	2	*0*	*1*
	Head Towards Speaker Frequency	3	*0*	*1*
	Ears Towards Speaker Frequency	2	*1*	2
	Ears Not Towards Speaker Freq.	2	1	1
	Lip Licking Frequency	4	*0*	*2*
	Non Feeding Latency	0.2	*50*	0.76
	Head Towards Speaker Latency	0.2	*50*	0.84
HILDA	Non Feeding Duration	6.6	**8.88**	6.44
	Head Towards Speaker Duration	1	2.56	**3.4**
	Ears Stationary Duration	47.96	47.96	48.78
	Non Feeding Frequency	1	**2**	**3**
	Head Towards Speaker Frequency	1	**3**	**3**
	Ears Towards Speaker Frequency	1	**2**	**3**
	Ears Not Towards Speaker Freq.	2	2	0
	Lip Licking Frequency	3	3	*0*
	Non Feeding Latency	0.88	0.16	0.36
	Head Towards Speaker Latency	0.88	0.88	0.36
JAZZ	Non Feeding Duration	6.72	*1.2*	**15.41**
	Head Towards Speaker Duration	0	**1.84**	1.52
	Ears Stationary Duration	48.87	49.13	**41.64**
	Non Feeding Frequency	1	1	**3**
	Head Towards Speaker Frequency	0	1	**2**
	Ears Towards Speaker Frequency	1	*0*	1
	Ears Not Towards Speaker Freq.	2	1	1
	Lip Licking Frequency	2	*0*	2
	Non Feeding Latency	15.24	4.8	6.92
	Head Towards Speaker Latency	0	4.2	6.92

Table 7.7: Variables recorded for each cat for the noise test. Values that are equal or more than one standard deviation away from the baseline value and in the direction of potential reduced welfare are highlighted in bold. Values equal or more than one standard deviation away from the baseline value and in the direction of potential increased welfare are

highlighted in red italics. Non Feeding Duration (SD=1.29); Head Towards Speaker Duration (SD=1.77); Ears Stationary Duration (SD=2.98); Non Feeding Frequency (SD=0.83); Head Towards Speaker Frequency (SD=1.30); Ears Towards Speaker Frequency (SD=0.50); Ears Not Towards Speaker Frequency (SD=0); Lip Licking Frequency (SD=0.71); Non Feeding Latency (SD=12.32); Head Towards Speaker Latency (SD=12.94).

Cats are very individual in their response to the noise test. Benji and Indi seemed to react less in the short term test and Benji reacted to the noise quicker in the longer term test, but Indi still showed a decrease in reaction. Hilda reacted consistently more in the short term and longer term testing, and so did Jazz, although it was less consistent. The potential anxiety/conflict like behaviour (lip licking) was present but the values are not very high and do not increase over time except for Benji in the longer term test.

7.3.4 Judgment bias test

Cat name	Location	Baseline	Short term	Longer term
BENJI	Near Rewarded	1.89	*1.12*	1.74
	Middle	2.65	2.08	*1.8*
	Near Unrewarded	15	*2.11*	*2.35*
INDI	Near Rewarded	1.88	2.24	*0.64*
	Middle	1.19	**2.03**	1.32
	Near Unrewarded	2.42	2.89	1.83
HILDA	Near Rewarded	0.77	1.03	0.62
	Middle	1.16	1.09	1.13
	Near Unrewarded	15	*1.24*	*1.23*

Table 7.8: Latencies of approach to ambiguous locations in the judgment bias test. Near Rewarded location (SD=0.53); Middle location (SD=0.70); Near Unrewarded location (SD=5.93). Values that are equal or more than one standard deviation away from the baseline value and in the direction of potential reduced welfare are highlighted in bold. Values equal or more than one standard deviation away from the baseline value and in the direction of potential increased welfare are highlighted in red italics.

Benji showed a decrease in latencies running to the near rewarded and near unrewarded locations in the short term testing, and this decrease shifted to the middle and the near unrewarded location in the longer term testing. Indi showed an increase in latency to the middle location in the short term test, and a decrease to the near rewarded location in the longer term test. Hilda showed consistent decrease in latencies to the near unrewarded location in the short term and longer term testing.

7.3.5 Questionnaire – owner observations of their cat's behaviour

Cat name	Variable	Baseline	Short Term	Longer Term
BENJI	Anxiety	0	1.2	0
	Outgoing	9	**6.8**	9
	Object	0	0	0
	Person	1.6	*1*	*0*
	Changes	7.7	7.5	*9*
	Long Lasting Hiding T	0.8	*0*	0.6
	Hissing T	0	0	0
	Scratching Object T	9	9	9
	Scratching People T	0	0	0
	Fighting with other Cats T	0	0	0
	Lip Licking T	0.8	*0*	*0*
	Short Sharp Rapid Grooming T	2.2	*0*	*0*
	Head Shaking T	0	0	0
	Skin Twitching T	1.5	*0*	*0*
	Tail Erected T	6.5	0	0
	Inappropriate Toileting T	0	0	0
	Social Interaction with Humans T	6.4	*9*	*9*
	Social Interaction with Cats T	9	9	9
	Play Interaction with Humans T	9	9	9
	Play Interaction on its Own T	9	9	7.2
INDI	Anxiety	5.4	4.3	*1.2*
	Outgoing	5.3	*7.1*	*8.4*
	Object	5.5	*1.8*	*0.5*
	Person	1.4	1.5	*0.6*
	Changes	6	**4.4**	*8.6*
	Long Lasting Hiding T	2.2	*0.4*	*0.4*
	Hissing T	0.5	*0*	*0*
	Scratching Object T	9	9	9
	Scratching People T	0	0	0
	Fighting with other Cats T	0	0	0
	Lip Licking T	0	0	0
	Short Sharp Rapid Grooming T	1.8	*0*	*0*
	Head Shaking T	0	0	0
	Skin Twitching T	0.7	*0*	*0*
	Tail Erected T	0.7	0	0
	Inappropriate Toileting T	0	0	0
	Social Interaction with Humans T	9	9	9
	Social Interaction with Cats T	9	9	9
	Play Interaction with Humans T	4.8	5	*9*
	Play Interaction on its Own T	3.6	5.2	4.8

Cat name	Variable	Baseline	Short Term	Longer Term
HILDA	Anxiety	2.3	1.7	2.2
	Outgoing	7.2	6.4	6.2
	Object	6.3	*0.7*	4.2
	Person	1.3	*0*	**4.3**
	Changes	7	*9*	6.7
	Long Lasting Hiding T	0.7	0	0.1
	Hissing T	1	1	*0*
	Scratching Object T	2	9	9
	Scratching People T	0	0	0
	Fighting with other Cats T	0	0	0
	Lip Licking T	0	0	0.1
	Short Sharp Rapid Grooming T	0	**1.1**	**2.1**
	Head Shaking T	0	0	**1.2**
	Skin Twitching T	0	0	**0.8**
	Tail Erected T	0.8	0	0.1
	Inappropriate Toileting T	0.8	0	0
	Social Interaction with Humans T	9	9	9
	Social Interaction with Cats T	2.2	0	1.9
	Play Interaction with Humans T	0	2.3	*4.5*
	PIOT	2.1	1.8	2.2
JAZZ	Anxiety	1.4	2.3	2.7
	Outgoing	7.7	8.6	8.4
	Object	0.5	0.3	0.8
	Person	0.5	0.3	0.5
	Changes	6.7	*8.6*	*8.5*
	Long Lasting Hiding T	0	0.7	**0.9**
	Hissing T	0.8	**1.2**	**2.7**
	Scratching Object T	9	3.2	2.1
	Scratching People T	0	**0.8**	**0.4**
	Fighting with other Cats T	4.1	*0.9*	2.7
	Lip Licking T	0.7	**1.5**	**4.8**
	Short Sharp Rapid Grooming T	0.6	**4.4**	**4.4**
	Head Shaking T	0	**0.7**	**1.1**
	Skin Twitching T	0	0.6	0.6
	Tail Erected T	4.8	2.3	1
	Inappropriate Toileting T	7.6	4.5	4.5
	Social Interaction with Humans T	9	9	9
	Social Interaction with Cats T	8.3	9	9
	Play Interaction with Humans T	9	9	7.6
	Play Interaction on its Own T	4.3	*9*	5

Table 7.9: Variables recorded for owner’s perception of behaviour in relation with behavioural tests (anx, outgo, obj, person) and perception of typical frequencies of behaviours. Values that are equal or more than one standard deviation away from the baseline value and in the direction of potential reduced welfare are highlighted in bold.

Values equal or more than one standard deviation away from the baseline value and in the direction of potential increased welfare are highlighted in italics. Anxiety= Cat anxiety (SD=1.98); outgoing=Cat confidence (SD=1.33); Object= Cat reaction to object (SD=2.84); Person= Cat reaction to a person (SD=0.42); Changes=Cat capacity to cope with changes (SD=0.61); and typical frequency of behaviour (T at the end of each variable stands for Typical Frequency) observed by owners: Long Lasting Hiding T (SD=0.80); Hissing T (SD=0.38); Scratching Object T (SD=3.03); Scratching People T (SD=0); Fighting with other Cats T (SD=1.78); Lip Licking T (SD=0.38); Short Sharp Rapid Grooming T (SD=0.89); Head Shaking T (SD=0) Skin Twitching T (SD=0.62) ; Tail Erected T (SD=2.52); Inappropriate Toileting T (SD=3.19); Social Interaction with Humans T (SD=1.13); Social Interaction with Cats T (SD=2.86); Play Interaction with Humans T (SD=3.71); Play Interaction on its Own T (SD=2.56).

For Benji, the owner reported only a mild decrease in confidence around the short term testing and a clear increase in welfare in the longer term testing, shown by the decrease in fearfulness to a person, and anxiety conflict and irritation behaviours. For Indi, the owner reported a mild decrease in the ability to cope with changes around the time of the short term test but in the longer term testing, the owner reported a decrease in anxiety, an increase in confidence, a decrease in irritation behaviour and an increase in playing interaction with humans. Clearly Indi’s owner perceived that their cat’s welfare had improved. For Hilda, the owner reported a mild increase in fearfulness of people, and a general mild increase in irritation behaviours around the longer term testing but also an increase in ability to cope with changes. Jazz is the cat for which the owner reported more changes. Both for the short term and longer term testing, irritation, anxiety/conflict like behaviour and arousal behaviour showed a mild increase.

7.3.6 Summary Tables

7.3.6.1 Unfamiliar person test

Here are the summary tables of measure variation for each cat and each test. D. stands for “Duration”, F. stands for “Frequency” and in the owner questionnaire, T. stands for “Typical Frequency”.

Unfamiliar person test	Cat name	Short Term		Long Term	
		Reduced Welfare	*Increased Welfare*	**Reduced Welfare**	*Increased Welfare*
	BENJI	Phase one Gaze Towards Stranger D. Phase Two Sniffing Stranger D. Sniffing Stranger F. Tail Up D. Lip Licking F. Phase Three Tail Up Frequency Gaze Towards Owner D. Phase Four None	Phase one Meowing F. Phase Two Meowing F. Phase Three Sniffing Owner D. Sniffing Owner F. Phase Four Meowing F.	Phase one None Phase Two Sniffing Stranger D. Sniffing Stranger F. Tail Up D. Phase Three Tail Up F. Phase Four None	Phase one Gaze Towards Stranger F. Meowing F. Phase Two Meowing F. Phase Three None Phase Four Gaze Towards Stranger D. Gaze Towards Stranger F. Self-Grooming D. Meowing F.
	INDI	Phase one None Phase Two Tail Up D. Lip Licking F. Phase Three None Phase Four Gaze Towards Stranger D. Gaze Towards Stranger F. Gaze Towards Owner D. Gaze Towards Owner F. Initiating Interaction with Owner F.	Phase one None Phase Two None Phase Three Gaze Towards Owner F. Phase Four Meowing F.	Phase one None Phase Two Meowing F. Phase Three None Phase Four Gaze Towards Owner D. Gaze Towards Owner F.	Phase one Tail Up D. Tail Up F. Phase Two None Phase Three None Phase Four Gaze Towards Stranger F. Meowing F.

HILDA	Phase one Meowing F. Phase Two Rubbing Stranger D. Phase Three None Phase Four Gaze Towards Stranger D. Gaze Towards Stranger F. Rubbing Stranger D. Rubbing Stranger F. Initiating Interaction with Stranger F. Gaze Towards Owner D.	Phase one None Phase Two Tail up D. Lip licking F. Meowing F. Phase Three Sniffing Owner F. Phase Four None	Phase one Gaze Towards Stranger D. Phase Two None Phase Three Sniffing Owner F. Sniffing Owner D. Phase Four Gaze Towards Stranger D. Gaze Towards Stranger F. Initiating Interaction with Stranger F.	Phase one None Phase Two Tail Up D. Lip Licking F. Meowing F. Phase Three Gaze Towards Owner F. Phase Four Tail Up D.
JAZZ	Phase one Gaze Towards Stranger D. Tail Up D. Meowing F. Phase Two Gaze Towards Stranger D. Sniffing Stranger F. Phase Three None Phase Four Gaze Towards Stranger D.	Phase one Meowing F. Phase Two Head Shaking F. Phase Three Gaze Towards Stranger D. Gaze Towards Stranger F. Tail Up D. Tail Up F. Gaze Towards Owner F. Phase Four Rubbing Stranger D. Rubbing Stranger F. Tail Up D. Meowing F. Gaze Towards Owner D.	N/A	N/A

Table 7.10: Summary of variable changes for each cat for the Unfamiliar Person test. D. stands for “Duration”, F. stands for “Frequency”.

7.3.6.2 Novel Object test

Novel object test	Cat name	Short Term		Long Term	
		Reduced Welfare	*Increased Welfare or increased interest for the object*	**Reduced Welfare**	*Increased Welfare or increased interest for the object*
	BENJI	Self-Grooming D. Gaze Towards Object F. Tail Up F. Self-Grooming F. Lip Licking F.	Near Object D. Sniffing Object F. Head Shaking F. Meowing F.	None	Head Shaking F. Meowing F. Ears Towards Object F.
	INDI	Sniffing Object D.	Tail Up D. Near Object F. Tail Up F. Meowing F.	Self-Grooming D.	Near Object D. Gaze Towards Object D. Sniffing Object D. Gaze Towards Object F. Sniffing Object F. Self-Grooming F. Head Shaking F. Ears Towards Object F.
	HILDA	Lip Licking F. Head Shaking F.	Near Object F. Gaze Towards Object F. Meowing F.	Head Shaking F.	Near Object D. Gaze Towards Object D. Self-Grooming D. Near Object F. Gaze Towards Object F. Lip Licking F. Sniffing Object F. Self-Grooming F. Meowing F. Ears Towards Object F.
	JAZZ	Tail Up D. Lip Licking F.	Near Object D. Gaze Towards Object D. Sniffing Object D. Gaze Towards Object F. Sniffing Object F.	Self-Grooming F. Head Shaking F.	Tail Up F. Ears Towards Object F.

Table 7.11: Summary of variable changes for each cat for the Novel Object test. D. stands for “Duration”, F. stands for “Frequency”.

7.3.6.3 Noise test

Noise test	Cat name	Short Term		Long Term	
		Reduced Welfare	*Increased Welfare*	**Reduced Welfare**	*Increased Welfare*
	BENJI	None	Head Towards Speaker D. Ears Stationary D. Non Feeding F. Head Towards Speaker F. Ears Towards Speaker F. Lip Licking F.	Ears Towards Speaker F. Lip Licking F. Non Feeding L. Head Towards Speaker L.	Non Feeding D. Ears Stationary D.
	INDI	None	Head Towards Speaker D. Ears Stationary D. Non Feeding F. Head Towards Speaker F. Lip Licking F. Non Feeding L. Head Towards Speaker L.	None	Non Feeding D. Ears Stationary D. Non Feeding F. Head Towards Speaker F. Lip Licking F.
	HILDA	Non Feeding D. Non Feeding F. Head Towards Speaker F. Ears Towards Speaker F.	None	Head Towards Speaker D. Non Feeding F. Head Towards Speaker F. Ears Towards Speaker F.	Lip Licking F.
	JAZZ	Head Towards Speaker D.	Non Feeding D. Ears Towards Speaker F. Lip Licking F.	Non Feeding D. Ears Stationary D. Non Feeding F. Head Towards Speaker F.	None

Table 7.12: Summary of variable changes for each cat for the Noise test. D. stands for “Duration”, F. stands for “Frequency”.

7.3.6.4 Judgment bias test

Judgment bias test	Cat name	Short Term		Long Term	
		Reduced Welfare	*Increased Welfare*	**Reduced Welfare**	*Increased Welfare*
	BENJI	None	Near Rewarded Near Unrewarded	None	Middle Near Unrewarded
	INDI	Middle	None	None	Near Rewarded
	HILDA	None	Near Unrewarded	None	Near Unrewarded

Table 7.13: Summary of variable changes for each cat for the Judgment bias test.

7.3.6.5 Owner questionnaire

Table 7.14: Summary of variable changes for each cat for the owner questionnaire. T stands for "Typical Frenquency"

Questionnaire	Cat name	Short Term		Long Term	
		Reduced Welfare	*Increased Welfare*	**Reduced Welfare**	*Increased Welfare*
	BENJI	Outgoing	Person Long Lasting Hiding T Lip Licking T Short Sharp Rapid Grooming T Skin Twitching T Social Interaction with Humans T	None	Person Lip Licking T Short Sharp Rapid Grooming T Skin Twitching T Social Interaction with Humans T
	INDI	Changes	Outgoing Long Lasting Hiding T Hissing T Short Sharp Rapid Grooming T Skin Twitching T	None	Anxiety Outgoing Object Person Changes Long Lasting Hiding T Hissing T Short Sharp Rapid Grooming T Skin Twitching T Play Interaction with Humans T
	HILDA	Short Sharp Rapid Grooming T	Object Person Changes	Person Short Sharp Rapid Grooming T Head Shaking T Skin Twitching T	Hissing T Play Interaction with Humans T
	JAZZ	Hissing T Scratching People T Lip Licking T Short Sharp Rapid Grooming T Head Shaking T	Changes Fighting with other Cats T Play Interaction on its Own T	Long Lasting Hiding T Hissing T Scratching People T Lip Licking T Short Sharp Rapid Grooming T Head Shaking T	Changes

7.4 Discussion

The purpose of the study was to gather initial information and impressions regarding the cats' response to the installation of the system, using behavioural tests, a judgment bias test and an owner questionnaire. The unfamiliar person test gives information about the cat's reaction to a person, but in this specific case it potentially gives information about the facts that cats might generalise their reaction to the containment system, to all kinds of novelty. Indeed, the containment system is a change in the cat's environment, and during training, involves a novel object in the form of the training flags. If the containment system has a negative impact on the cat's welfare, it might be expected that the cat may develop a more general neophobia to a range of novel/unfamiliar stimulus, such as an unfamiliar person. This was not the case in my findings. The cats showed some changes, but no cats showed changes that would indicate increased anxiety around the unfamiliar person during the whole duration of the unfamiliar person test. In fact, gazes towards the stranger, interaction with the stranger and greeting behaviours appear in general to increase over time with repeated testing. Even though the batch of tests were spaced over time, with around three weeks between the first two, and 10 to 14 weeks between the second and third test, the cats' response to the unfamiliar person may have been influenced by the fact that the testing situation was not new to the cats over time, and that the unfamiliar person was the same person. Behaviour may change with repeated testing (McIlwain et al. 2001; Blokland et al. 2012) and my findings confirm those of previous studies on cats (Mertens and Turner 1988; Mertens 1991) where cats interact more with people that spend time in the home. Moreover, positive emotional memories associated with positive interactions with the unfamiliar person and food may also have been established over time.

In the case of the novel object test, the test gives us different, more direct information, at different levels: how the cat responds to a novel object over time may mimic more directly its reaction to the containment system. The novelty of the object, without any social component, is more likely to mimic the novelty of the system. The findings showed that in the short term testing, nearly all cats displayed more potential anxiety/conflict like behaviours and one cat showed a strong interest in the object. It showed that their relationship with a novel object and potentially novelty more widely has changed. It might be that the cats were motivated to assess the novel object more fully. In a stressful situation, it is generally reported that individuals tend to explore a novel object less (Hillman et al. 2003 in piglets; Moretti et al. 2015 in dogs and wolves). However, in my study the cats investigated the object, showing that if the object triggered any anxiety the anxiety was mild enough for them to approach the object despite the situation. Moreover, in the novel object test, the object presented in the three occurrences was different each time, so, even if the cats had habituated to the test situation, the object presented was still new. Research shows that habituation may help decrease the initial response to a novel object (e.g. in horses Leiner and Fendt 2011) but that for generalisation, at least in horses, the object may need to be of a very similar colour (Winther Christensen et al. 2008). In the current study, the objects were different in shape and colour, so the change in the cats' response to the object is not likely to be the result of generalisation. These results might indicate that at the time of the short term testing (ie 10-14 days after installation of the system), the cats showed increased interest in novelty. The other interesting finding is that in the longer term testing, for all but one of the cats, the potential anxiety/conflict like behaviours did not show an increase; for the remaining cat the values are indeed higher than for the first test, but lower than for the short term test. So, if the system is increasing anxiety and interest in novelty, this effect seems to be transitory. In this regard, the cat "Indi" appeared to react a bit differently, because the increased interest in novelty was more during the longer term testing and with no increase in potential anxiety/conflict like behaviours. Such individual differences are very important when considering the welfare of individuals (Durr and Smith 1997).

The noise test is also a direct test in more than one way. Not only does it potentially give us information about how the cat would react to a sudden noise, which is exactly what happens when the cat approaches the boundary in the containment system, but it also gives us potential information about the cat's tendency to generalise its reaction to sudden noises outside the specific context of being near the fence. The findings showed that there was no consistency between cats: two cats (Benji and Indi) seem to follow an inverted curve, reacting moderately before the system's installation, then reacting less than before in the short term testing, and finally reacting mildly in the longer term testing, while two other cats (Hilda and Jazz) reacted more after the installation of the system than before.

The judgment bias test perhaps gives us potential information about the cat's mood, and its development over time following the installation of the containment system. It has been used to detect both long lasting (Matheson et al. 2008) and transitory (Burman et al. 2009) changes in affective state, and is perhaps the most powerful of the measures used to assess the welfare of the cats. Only three cats performed the test. Two showed a decrease in latency (increase in running speed) to the near unrewarded position during the short and longer term testing, which would suggest increased optimism. But it might also be that because this test was based on food rewards and repeated over time, that repetition of the training and testing alone resulted in a reduced latency. Without a control group it is not easy to distinguish between these possibilities.

Finally, the questionnaire gives us a complementary approach to the direct behavioural and cognitive assessment of the cats themselves, by tapping into the spontaneous behaviour of the cat (outside of testing days), while also giving us an insight into the owner's perceptions of their cat's behaviour. Two owners reported strong changes in their cat; changes that did not go the same way. For one cat (Indi) there was clearly a perceived increase in welfare, whereas for the other cat (Jazz), there was a perceived decrease in welfare. These changes in values may reflect a real change in behaviour from the cat, and it is worth noting that the system was used in an unusual way with Jazz - to stop him entering a neighbour's garden and attacking their cat. This might be a more frustrating application of the system and deserves further investigation, but it is also probably quite an uncommon way of using the system (i.e. for exclusion rather than safe containment).

Case studies generally provide a low level of evidence for evaluating hypotheses, but rather should be used to provide initial information about a subject, the strength of an effect or to generate hypotheses for higher level evidence studies (Burns et al. 2011). Therefore it is not appropriate to generalise the findings of this case study to the general population, especially given the small number of cats and the lack of consistency between cats across several tests. However, the variability of these findings indicates there is not an overwhelming problem from the use of containment systems, but nor do they exclude the potential for problems in some circumstances or for some individuals.

Considering the results as a whole for each cat, different possible profiles might be describable, but none can be directly attributed to the containment system with any certainty. For Benji, the novel object test and the owner questionnaire might indicate a transitory state of anxiety and a drop of confidence around the short term testing, but any such effect seems to be transitory, although his sensitivity to noise might have been heightened in the longer term. Indi appeared to have a strong interest in the novel object in the longer term and his owner clearly perceived increased welfare at the same time. The increased interest in the novel object in the longer term is an anomaly compared to the other cats, but it is also the strongest potential effect in this individual. Hilda showed more complex or possibly random changes, specifically a decrease in interacting with owner and stranger during the unfamiliar person test, a possible transitory increase in anxiety/conflict like behaviours for the novel object test (short term testing), an interest in the novel object test in the longer term testing, and a reaction to the noise test after the installation of the fence, with a possible increase in mild irritation behaviours reported from the owner questionnaire. However, Hilda was the last to arrive in a multi-cat household and complementary data from trap cameras (not included in this thesis) showed that she hardly approached the boundary. This information might indicate that other features, like the domestic social dynamic within a multi-cat household, may have an important role to play in explaining any of these effects. Finally, Jazz was the cat that showed the most reaction, a strong interest towards the novel object in the short term testing and an increased reactivity to the noise test over time, matching its owner's perception of increased irritation and anxiety behaviours. However, the reactions and increase in anxiety and irritation behaviour were mild. Jazz is the only cat in this case series where the system was used to prevent him from accessing a neighbour's garden rather than confining him to the boundaries of its owner's property. It might be that this specific use of the system triggered frustration, at least during the short term and longer term testing.

7.5 Conclusion

Altogether, there is no evidence to suggest that the system has a consistent and lasting substantial negative effect on the cats as studied here. There might be an increased curiosity and potentially a mild increase in anxiety around novelty in the short term, and some individuals might become more sensitive to a sudden noise after the installation of the system, but a larger controlled study would be necessary to determine if these possible effects are reliable enough and of sufficient magnitude to warrant concern. Specifically, for one cat (Indi), the added space from being allowed to go outside seemed to have boosted its 'confidence', according to its owner. In another cat (Jazz) where the system was used to exclude it from a neighbour's garden where it was causing problems to a neighbour's cat, it might be that the system has a more negative effect. But, arresting this behaviour, like preventing free-roaming, appeared to have at most a mild and possibly transitory effect on the cat's welfare. Nonetheless, further investigation on a more readily accessible population, in larger numbers, and with a proper control group is warranted.

Chapter Eight

Cat containment study - does long-term exposure to an electronic containment system impact on domestic owned cat behaviour and welfare?

This chapter describes a study that investigated the long-term effects on cat behaviour and welfare of exposure to an electronic containment system.

8.1 Introduction

There is little to no published research on the long term effect of exposure to an electronic containment system. As stated in Chapter 7, research has investigated the efficacy of electronic containment system on several species including cattle (Tibbs et al. 1995; Tiedemann et al. 1999; Lee et al. 2009; Umstatter et al. 2015) and sheep (Jouven et al. 2012). These found that the animals were able to learn to avoid exclusion areas and to associate an audio cue with the potentially of the electric correction (Lee et al. 2009). However, in all the studies, the exposure to the containment system was not always constant, and ranged from a few hours (Jouven et al. 2012) to two months (Tiedemann et al. 1999). I was not able to find a published study on an electronic containment system to which animals had been exposed for longer periods, such as from one to several years. When containment systems are used with a companion animal such as the cat, it is likely to be used for several years (given that domestic owned cats live for roughly 15 to 16 years on average). Therefore the possibility of compromised welfare potentially increases. Frustration related to the fact of being contained, for example for the cat being prevented to pursue a prey in a hunting attempt (Dickman and Newsome 2015); or an agonistic encounter that the cat is unable to escape from because of the containment system, can be considered as “stressors”. If the stressors are repeated over time, it may lead to a state of chronic stress, and therefore to compromised welfare. Chronic stress is known to prompt changes in the affective state of an animal: it increases anxiety (in mice, Huynh et al 2011); induces pessimistic judgement and learning deficit (in sheep, Destrez et al. 2013b) and shifts behavioural response to a more rigid stimulus-response learning strategy (in mice and man; Schwabe et al. 2008). Chronic stress also appears to alter spatial learning and memory, although most of the studies reviewed are in rodents (Conrad 2010). So if events perceived by the cat as aversive were to be repeated over time, it may lead to the cat being chronically stressed and cat welfare to decrease. Therefore the purpose of the study was to investigate the long-term effect on the behaviour and welfare of the cat – specifically the potential effect on their affective state – following exposure to an electronic containment system, by studying cats that have been exposed to the containment system for more than 12 months in comparison to those that have never experience electronic containment. I hypothesised that if AF cats were to be more anxious as a result of the electronic containment system, then they would interact less with the unfamiliar person, explore and interact less with the novel object, have a heightened sensitivity to sudden noise especially when the noise is high pitch, and that their anxiety would be reflected in the owner's report.

8.2 Methods

The subjects were recruited in two groups: AF (already have a fence) group and C (control group). Each group consisted of 23 cats, with 10 females and 13 males in each group. All cats were neutered and aged from 1 to 15 years old. AF cats had been exposed to the containment system for more than 12 months.

The testing procedure used in this chapter has already been described in details in Chapter 6. Here, therefore, I simply describe the specific statistical analysis applied to each test in order to compare the AF (already have a fence) group with the C (control) group. As stated earlier (see Chapter 6), all behaviours that were not performed by at least 20% of the cats (in my study, behaviours performed by less than eight cats) were removed from analysis. Due to the high number of remaining different behaviours to analyse, a data reduction was performed using a factor analysis (FA). Even with a small sample size (below 50 subjects), a FA is possible provided that the variables are well correlated and that sample adequacy is achieved (de Winter et al. 2009). In order to achieve sample adequacy, a Kaiser-Meyer-Olkin measure of sample adequacy (KMO; Kaiser 1970) was used, overall and on individual variables, with 0.6 taken as the absolute minimum value for the overall KMO measure, and 0.5 as an absolute minimum for individual KMO measure (Field 2009).

Then Bartlett's test of sphericity was used to assess the suitability of the data to perform the analysis. Analysis was performed only when the Bartlett's test of sphericity result was significant ($p<0.05$). Factors were retained as a "factor of interest" when reaching at least two of the three following criteria: an eigen value > 0.9; explaining 10% or more of the variance; is before or includes the inflexion point in a visual inspection of the scree plot. The variables retained to explain the factor were the ones which loaded ≥ 0.5 on the factor, positively or negatively. When a FA was possible (according to the KMO measures), this was performed with an orthogonal rotation (varimax; Field 2009). All data were tested for normality using the Shapiro-Wilk test with p value set at 0.05. When $p\leq0.05$, the data was not distributed normally therefore a non-parametric Mann Whitney U test was performed. When $p\geq0.05$, the data was distributed normally therefore an independent t test was performed. When it was not possible (i.e. sample adequacy was not achieved) or when sample adequacy was achieved with a fewer number of behaviours than initially retained, individual behaviours of interest were tested for normality and analysed as previously stated depending on the normality test results.

8.2.1 Unfamiliar person test

Due to the circumstances of the test (i.e. a field study carried out in the home environment with fixed camcorders), cats were not always in the camera field of view. In order, therefore, to compare durations and frequencies of behaviours between cats, all variable values were divided either: by the time that the cat was visible (for the cat body); by the time the gaze was visible (for "gaze behaviours"); and by the time the tail was visible (for "tail behaviours"). Vocalisations were divided only by the phase duration. This yielded values that were a proportion of behaviour per second, therefore comparable between cats and between groups. Each analysis was performed phase by phase. All statistical analyses were performed using SPSS (version 22) software.

8.2.1.1 Phase One: unfamiliar person alone with cat, person passive

After initial data inspection, five behaviours remained for analysis: "gaze towards stranger" duration and frequency; "tail up" duration; "head shaking" frequency and "lip licking" frequency. Data was tested for normality and (being non-normal) comparison between the AF and C group was performed using a non-parametric Mann Whitney U test.

8.2.1.2 Phase Two: unfamiliar person alone with cat, person active

After initial inspection, 11 behaviours remained for analysis. During phase two, six behaviours achieved sample adequacy during factor analysis and individual behaviours of interest were selected in the remaining five behaviours to be analysed (Table 8.1).

Behaviour included	Behaviour removed
Gaze Towards Stranger Duration	Gaze Towards Stranger Frequency
Sniffing Stranger Duration	Rubbing Stranger Duration
Sniffing Stranger Frequency	Rubbing Stranger Frequency
Tail Up Duration	Initiating Interaction with Stranger Frequency
Self-Grooming Duration	Head Shaking Frequency
Lip Licking Frequency	

Table 8.1: Behaviours included and removed from the FA for Phase two.

8.2.1.3 Phase Three: owner and unfamiliar person present, both passive

After initial data inspection, seven behaviours were entered in a FA, and six behaviours were retained to achieve sample adequacy (Table 8.2).

Behaviour included	Behaviour removed
Gaze Towards Stranger Duration	Gaze Towards Stranger Frequency
Tail Up Duration	
Lip Licking Frequency	
Meowing Frequency	
Gaze Towards Owner Duration	
Gaze Towards Owner Frequency	

Table 8.2: Behaviours included and removed from the FA for Phase three.

8.2.1.4 Phase Four: owner passive, unfamiliar person active

After initial data inspection, 13 behaviours were entered in a FA. Eight behaviours were retained to achieve sample adequacy and individual behaviours of interest were selected in the remaining five behaviours to be analysed (Table 8.3).

Behaviour included	Behaviour removed
Gaze Towards Stranger Frequency	Gaze Towards Stranger Duration
Sniffing Stranger Duration	Rubbing Stranger Duration
Sniffing Stranger Frequency	Self-Grooming Duration
Rubbing Stranger Frequency	Lip Licking Frequency
Initiating Interaction with Stranger Frequency	Gaze Towards Owner Duration
Tail Up Duration	
Self-Grooming Frequency	
Gaze Towards Owner Frequency	

Table 8.3: Behaviours included and removed from the FA for Phase four.

8.2.2 Novel object test

After initial data inspection, 15 behaviours were entered in a FA. Eight behaviours were retained to achieve sample adequacy and individual behaviours of interest were selected in the remaining seven behaviours to be analysed (Table 8.4).

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Behaviour included	Behaviour removed
Near Object Duration	Gaze Towards Experimenter Duration
Gaze Towards Object Duration	Gaze Towards Door Duration
Sniffing Object Duration	Tail Up Duration
Self-Grooming Duration	Gaze Towards Object Frequency
Near Object Frequency	Gaze Towards Experimenter Frequency
Sniffing Object Frequency	Gaze Towards Door Frequency
Self-Grooming Frequency	Ears Towards Object Frequency
Lip Licking Frequency	

Table 8.4: Behaviours included from the FA for the novel object test.

8.2.3 Noise test

After initial data inspection, 11 behaviours remained to analyse and were entered in a FA. Nine behaviours were retained to achieve sample adequacy (Table 8.5).

Behaviour included	Behaviour removed
Non Feeding Duration	Ears Towards Speaker Frequency
Head Towards Speaker Duration	Ears Not Towards Speaker Frequency
Ears Stationary Duration	
Non Feeding Frequency	
Head Towards Speaker Frequency	
Ears Stationary Frequency	
Lip Licking Frequency	
Non Feeding Latency	
Head Towards Speaker Latency	

Table 8.5: Behaviours included and removed from the FA for the noise test.

8.2.4 Cognitive bias test

On the first test occurrence, six AF cats and 10 C cats performed the test. Potential differences in latencies to the ambiguous locations were investigated by means of a General Linear Model (GLM) with Treatment (AF/C) as a between-subjects factor and Location (NR= Near Rewarded/M=Middle/NU=Near Unrewarded) as a within-subjects factor. Regarding learning, the number of trials to reach the criterion was compared between groups using an independent samples t test.

8.2.5 Owner questionnaire

The questionnaire was divided in four parts: results in part one were descriptive. For part two, difference between AF owners and C owners regarding “time spent interacting with the cat”, “time spent outdoor by the cat”, “cat health”, “cat abnormal or problematic behaviour”, as well the 14 enrichment items provided for the cat, were investigated by mean of a chi square test. Regarding part three and opinion about the cats’ anxiety, confidence, and response to a novel object or a novel person, measure on a visual analogue scale, data was tested for normality and differences between AF and C groups investigated using a Mann Whitney U test. Finally, part four measured the typical frequency and the last week frequency of 15 behaviours (adding to 30 variables). A Spearman’s correlation was used to reduce the number of behaviours for analysis, then the 15 remaining behaviours were entered in a FA. Seven behaviours were retained to achieve sample adequacy.

Behaviour included	Behaviour removed
Long Lasting Hiding T	Scratching Object T
Hissing T	Scratching People T
Head ShakingT	Fighting with other Cats T
Skin Twitching T	Lip Licking T
Tail Erected T	Short Sharp Rapid Groom T
Social Interaction with Cats T	Inappropriate Toileting T
Play Interaction with Humans T	Social Interaction with Humans T
	Play Interaction on its Own T

Table 8.6: Behaviour included and removed from the FA for the owner questionnaire. The T at the end of each variable stands for “Typical Frequency”.

8.3 Results

8.3.1 Unfamiliar person test

8.2.1.1 Phase One: unfamiliar person alone with cat, person passive

There was a significant difference between AF and C groups only for “lip licking” (U=219, Z=2.732, p=0.029), with C cats “lip licking” more than AF cats. All other behaviours showed no significant difference between groups (p>0.05).

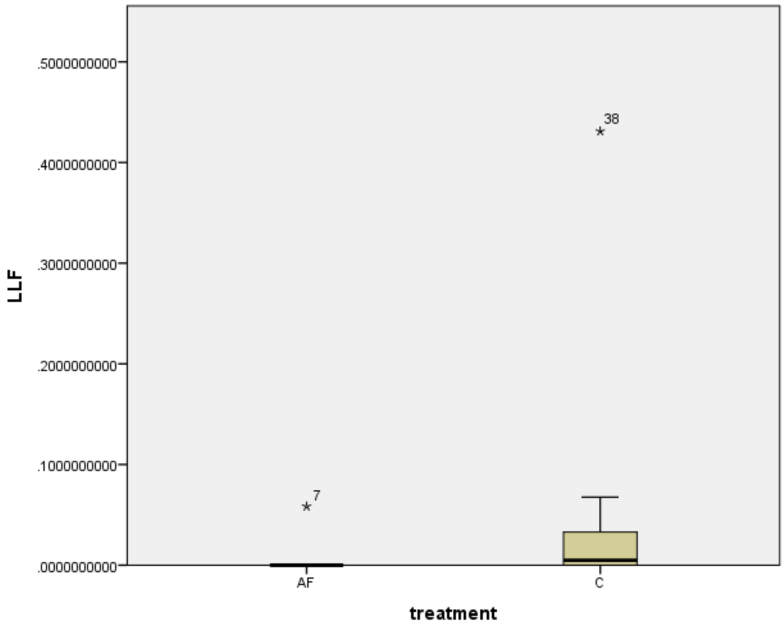

Figure 8.1: Boxplot (medians and interquartile range) of proportion of “lip licking” frequency per second for AF group and C group.

8.2.1.2 Phase Two: unfamiliar person alone with cat, active

The FA yielded a KMO measure of 0.695. Bartlett’s test of sphericity (chi square (15)=51.881, p<0.0005) indicated that the data were suitable for a FA. Two factors were extracted during the analysis, which explained 64.66% of the variance. Factor one was labelled as “Looking at and exploring the stranger”, and factor two “Confidence” as the greeting behaviour load positively on the factor while the anxiety/conflict like behaviours load negatively on this factor (see Table 8.7).

Behaviour	factor one: looking at and exploring the stranger	factor two: confidence
Sniffing Stranger Duration	**0.883**	0.133
Sniffing Stranger Frequency	**0.868**	0.263
Gaze Towards Stranger Duration	**0.799**	0.131
Tail Up Duration	0.170	**0.815**
Lip Licking Frequency	<0.1	**-0.695**
Self-Grooming Duration	-0.205	**-0.617**

Table 8.7: Behaviour variables loadings on the two factors of interest extracted. The factors’ components are highlighted in bold.

The extracted factor data was normally distributed so differences between groups were tested using an independent t-test. Homogeneity of variance was assessed by Levene's test and found non homogenous ($F=6.697$, $p=0.015$ for factor one; $F=7.307$, $p=0.011$ for factor two). There was a significant difference between AF (mean plus SE 0.413 +/- 0.309) and C (mean plus SE -0.387 +/- 0.119) group for factor one "looking and exploring the stranger" $t(18.033)=2.335$; $p=0.031$ (see Figure 8.2).

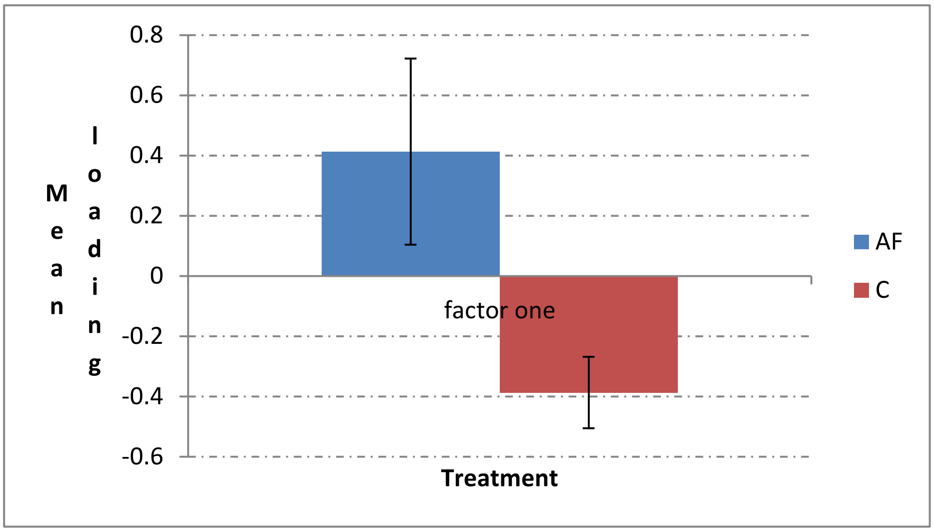

Figure 8.2: Mean plus standard error for loading on factor one "looking at and exploring the stranger" for phase two, AF group and C group.

There was no significant difference between AF and C group for factor two "confidence" ($p>0.05$). Regarding individual behaviours of interest (i.e. those that could not be included in the factor analysis), frequency of "rubbing stranger" and frequency of "head shaking" were selected for analysis. There were no significant differences (Mann Whitney U test; $P>0.05$) found either for "rubbing stranger" frequency or "head shaking" frequency between AF and C group.

8.2.1.3 Phase Three: owner and unfamiliar person present, passive

The FA yielded a KMO measure of 0.637. Bartlett's test of sphericity (chi square $(15)=35.645$, $p=0.005$) indicated that the data was suitable for a FA. Two factors were extracted during the analysis, which explained 60.37% of the variance. Factor one was named "looking at owner and greeting behaviour", and factor two "not looking at stranger and anxiety" as "gaze towards stranger" loaded negatively on this factor while the anxiety/conflict like behaviours loaded positively (see Table 8.8).

Behaviour	factor one: looking at owner and greeting behaviour	factor two: not looking at stranger and anxiety
Gaze Towards Owner Frequency	**0.71**	0.407
Gaze Towards Owner Duration	**0.868**	0.111
Tail Up Duration	**0.742**	<0.1
Gaze Towards Stranger Duration	0.399	**-0.572**
Meowing Frequency	0.137	**0.764**
Lip Licking Frequency	0.19	**0.71**

Table 8.8: Behaviour variables loadings on the two factors of interest extracted. The factors' components are highlighted in bold.

There were no significant differences between AF and C group for the two factors "looking at owner and greeting behaviour" and "not looking at stranger and anxiety" (Mann Whitney U test, p>0.05).

8.2.1.4 Phase Four: owner passive, unfamiliar person active

The FA yielded a KMO measure of 0.691. Bartlett's test of sphericity (chi square (28)=81.913, p<0.0005) indicated that the data were suitable for a FA. Two factors were extracted during the analysis, which explained 60.81% of the variance. Factor one was named "interaction with stranger", and factor two "gazes and positive behaviour" as the greeting behaviour loaded positively on this factor while the anxiety/conflict like behaviour loaded negatively (see Table 8.9).

Behaviour	factor one: interaction with stranger	factor two: gazes and positive behaviour
Sniffing Stranger Frequency	**0.913**	0.241
Initiating Interaction with Stranger Frequency	**0.763**	0.451
Rubbing Stranger Frequency	**0.736**	0.235
Sniffing Stranger Duration	**0.641**	<0.1
Self-Grooming Frequency	<0.1	**-0.797**
Tail Up Duration	0.239	**0.722**
Gaze Towards Stranger Frequency	0.229	**0.655**
Gaze Towards Owner Frequency	0.484	**0.486**

Table 8.9: Behaviour variables loadings on the two factors of interest extracted. The factors' components are highlighted in bold.

Differences between groups were tested using an independent t-test. Homogeneity of variance was assessed by Levene's test and found non homogenous for factor one (F=5.697, p=0.025) and homogenous for factor two (F=2.061, p=0.164). There was a significant difference between AF (mean plus SE 0.396 +/- 0.294) and C (mean plus SE -0.495 +/- 0.135) group for factor one "interaction with stranger" t(19.859)=2.734; p=0.013, with AF cats scoring, on average, higher for this factor. (see Figure 8.3).

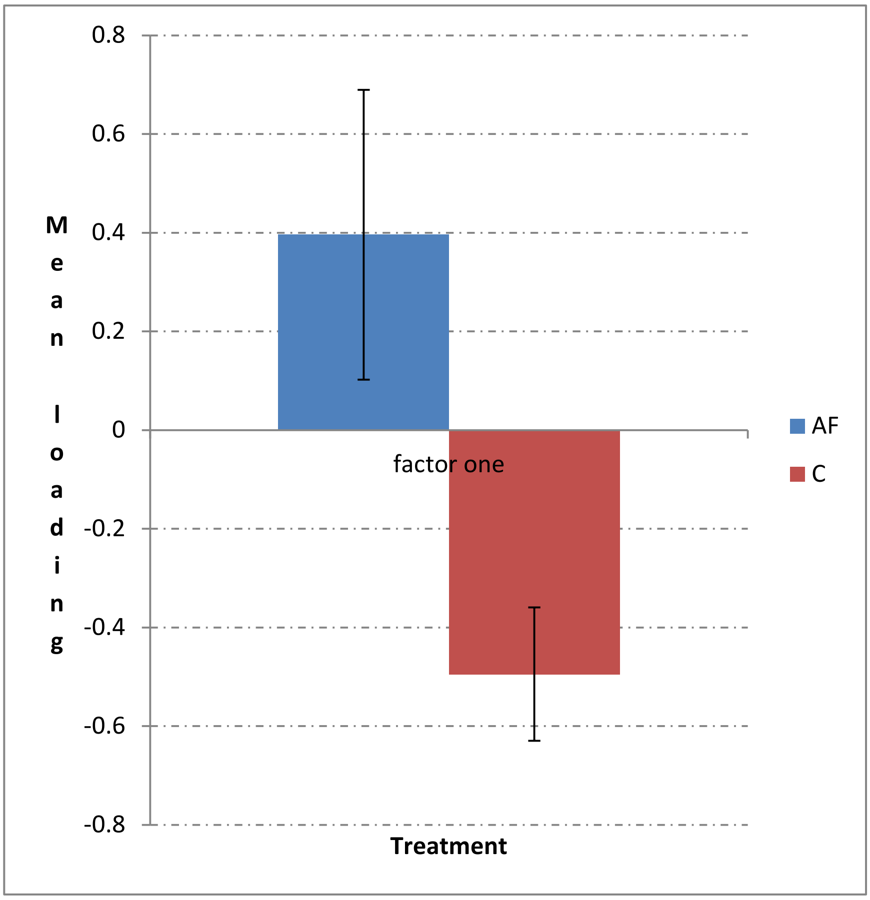

Figure 8.3: Mean plus standard error for loading on factor one for phase two, AF group and C group.

There was no significant difference (p>0.05) between AF and C group for factor two "gazes and positive behaviour". Regarding individual behaviours of interest, anxiety/conflict like behaviours were selected for analysis (i.e. "lip licking" and "self-grooming" duration). There were no significant differences either for "lip licking" or "self-grooming" duration between AF and C group (Mann Whitney U test; p>0.05).

8.3.2 Novel object test

The FA yielded a KMO measure of 0.657. Bartlett's test of sphericity (chi square (28)=179.742, p<0.0005) indicated that the data were suitable for a FA. Three factors were extracted during the analysis that explained 79.91% of the variance. Factor one was named "looking at and exploring object", factor two "anxiety/conflict like behaviour" and factor three "time spent near the object" (see Table 8.10).

Behaviour	factor one: looking at and exploring object	factor two: anxiety/conflict like behaviour	factor three: time spent near the object
Sniffing Object Duration	**0.93**	<0.1	<0.1
Gaze Towards Object Duration	**0.908**	<0.1	<0.1
Sniffing Object Frequency	**0.886**	<0.1	0.333
Self-Grooming Frequency	<0.1	**0.884**	<0.1
Self-Grooming Duration	<0.1	**0.838**	<0.1
Lip Licking Frequency	<0.1	**0.724**	<0.1
Near Object Frequency	<0.1	<0.1	**0.893**
Near Object Duration	0.405	0.319	**0.709**

Table 8.10: Behaviour variables loadings on the three factors of interest extracted. The factors' components are highlighted in bold.

There was a significant difference between the groups for factor one "looking at and exploring object" (Mann Whitney U test; U=107, Z=-2.516, p=0.012), with AF cats exploring the object more than C cats (see Figure 8.4).

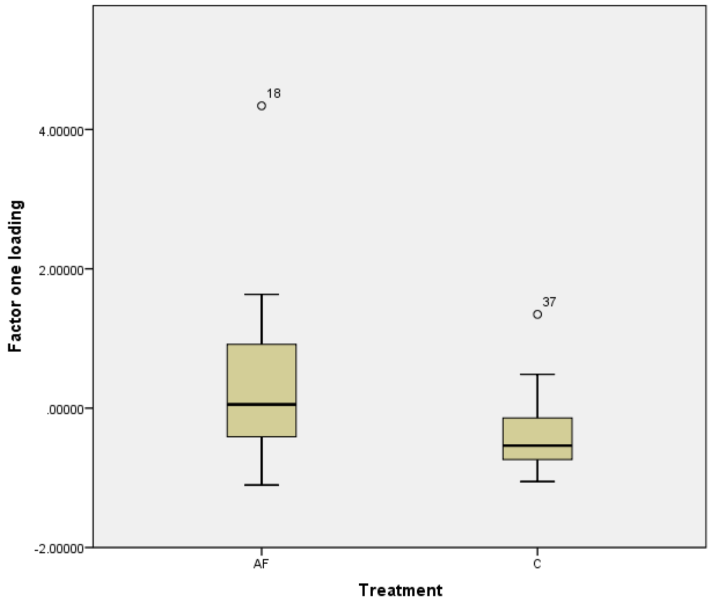

Figure 8.4: Boxplot (median and interquartile range) of factor one loadings for AF group and C group.

There were no significant differences between AF and C groups for factor two anxiety/conflict like behaviour" and factor three "time spent near the object" (Mann Whitney U test; p>0.05) Regarding individual behaviours of interest, two durations were selected to investigate the cats' reaction to the test situation ("gaze towards the experimenter", "gaze towards the door"), one for greeting behaviour ("tail up" duration) as well as “ear towards object” frequency. Data were not normally distributed, therefore a Mann Whitney U test was used and no significant differences were found for any of the behaviours (p>0.05).

8.3.3 Noise test

The FA yielded a KMO measure of 0.701. Bartlett’s test of sphericity (chi square (36)=226.523, p<0.0005) indicated that the data were suitable for a FA. Two factors were extracted during the analysis, which explained 69.67% of the variance. Factor one was named “reaction to the sudden noise”, factor two “non reaction” because “ear stationary” and “non feeding latency” load positively while “non feeding” duration load negatively on the factor (see Table 8.11).

Behaviour	Factor one: reaction to the sudden noise	Factor two: non reaction
Head Towards Speaker Duration	**0.895**	<0.1
Head Towards Speaker Frequency	**0.865**	<0.1
Lip Licking Frequency	**0.825**	<0.1
Ears Stationary Frequency	**0.821**	<0.1
Non Feeding Frequency	**0.729**	-0.359
Head Towards Speaker Latency	**-0.626**	0.471
Non Feeding Latency	-0.492	**0.536**
Ear Stationary Duration	<0.1	**0.889**
Non Feeding Duration	<0.1	**-0.597**

Table 8.11: Behaviour variables loadings on the two factors of interest extracted. The factors’ components are highlighted in bold.

The extracted factor data was distributed normally for factor one “reaction to the sudden noise” (p>0.05) and was not normally distributed for factor two “non reaction” (p<0.05). No significant differences were found for either factor.

8.4 Cognitive bias test

Five AF cats and nine C cats were included in the final model. Data was transformed by using the log10 transformation in order to achiever normality, as assessed by Shapiro-Wilk’s test (p>0.05 for all locations and groups except AF group for near unrewarded location). Significant differences were found between response to the ambiguous locations, with latency to the near unrewarded location significantly higher than the latencies for the near rewarded and the middle ambiguous locations (F=7.072, p=0.021; see Figure 8.5). However, no significant differences were found between AF and C group.

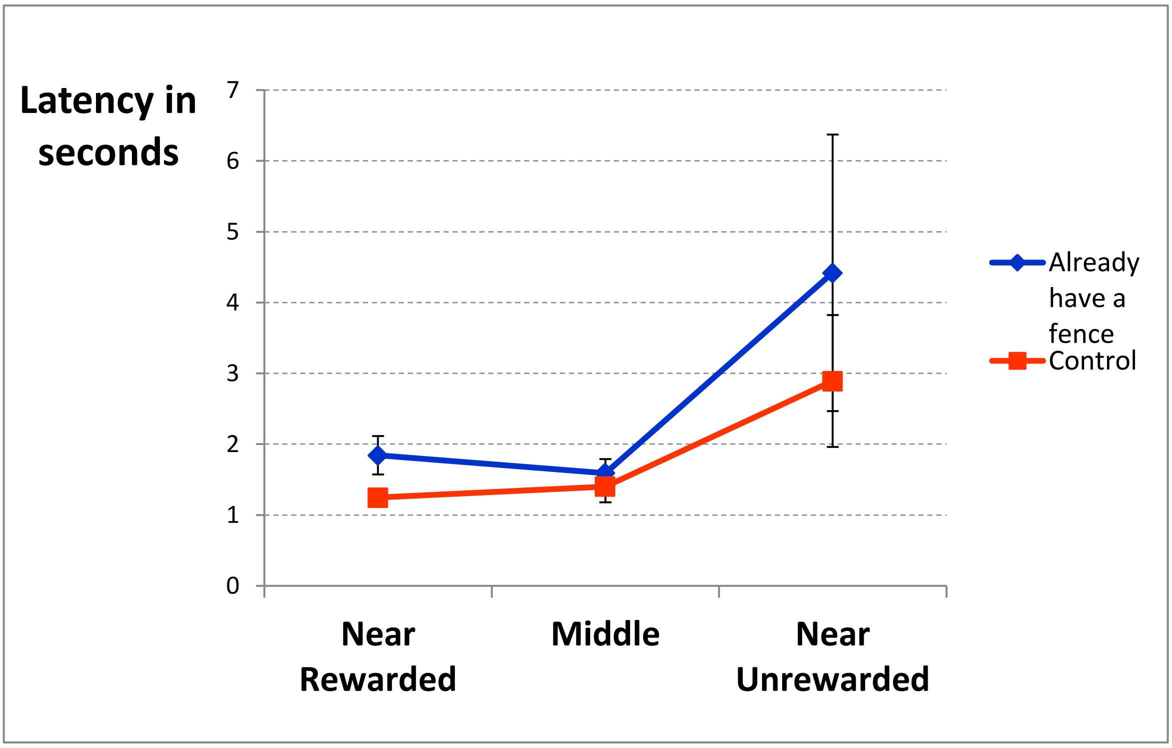

Figure 8.5: Ambiguous locations latencies for the cognitive bias test between AF and C group.

Regarding learning, there were no statistically significant differences between groups regarding the number of trials to reach the criterion (see Figure 8.6) ($p>0.05$).

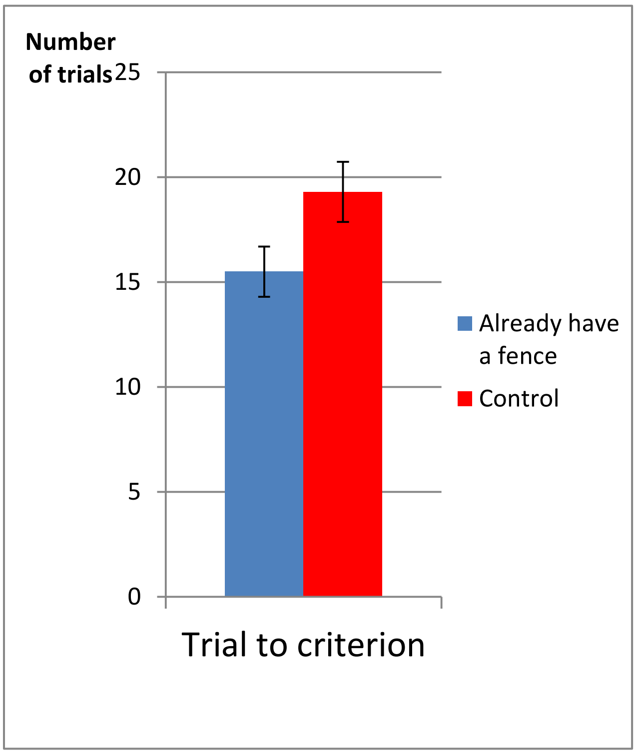

Figure 8.6: Trial to criterion (mean plus standard error) for AF and C group.

8.5 Owner questionnaire

8.1 Demographics and reasons to install the containment system

The AF group included 13 separate households, with nine multi-cat households. The cats were 10 females, 13 males, with ages ranging from 1 to 15 years old, all neutered. For the C group, it included 14 separate households with seven multi-cat households. The cats were 10 females, 13 males, with ages ranging from 2 to 13 years old, all neutered. Most of the AF owners in the study (all but one) stated that they had installed the containment system to keep their cat safe from the risk of road traffic accidents. The size of the contained area ranged from $120m^2$ to $28000m^2$. Most of the cats in the two groups were neutered at around six months of age, with the exception of cats adopted as adults (four cats on the total of 46).

8.2 Questions about the cat-owner interaction, the time spent outside by the cat and perception of owners about the health and stress of their cat, and provision of enrichment in the home

There were no differences in the perception of owners regarding the time spent interacting with their cat, the time spent outdoors by the cat and their cat's health. Most owners thought that their cat did not display any behaviour that could be considered unusual, abnormal or problematic and there was no significant difference between the groups. Regarding the 14 items available to the cat inside the home, there was a significant difference between AF and C groups of owners for the item "litter tray" (AF 22/23 providing and C 14/23; Pearson's chi square (1)=8.178, p=0.004) and the item "scratching post" (AF 21/23 providing and C 14/23 Pearson's chi square (1)=5.855, p=0.016), i.e more AF owners provided litter trays and scratching posts than C owners.

8.3 Questions about the owner's perception of their cats' reaction to a novel object, novel person, and their view of their cats' anxiety and confidence

There was no significant difference between the AF and C cats in their owner's perception of how their cat reacted to novel objects, novel people, about their cat's anxiety and confidence (p>0.05).

8.4 Questions about the behaviours observed by owners, indicating positive emotions and negative emotions

The FA yielded a KMO measure of 0.624. Bartlett's test of sphericity (chi square (21)=39.424, p=0.009) indicated that the data is suitable for a FA. Three factors were extracted during the analysis, which explained 63.1% of the variance. Factor one was named “irritability” because irritability behaviours load positively and “social interaction with cats” load negatively on that factor. Factor two was named “arousal” that can be in a indicating positive arousal “playing interaction with human” and “tail erected” (often during play according to owners) or stress with “long lasting hiding”. Factor three is the behaviour “hissing or growling” (see Table 8.12)

Behaviour	factor one “irritability”	factor two “arousal”	factor three “hissing or growling”
Social Interaction with Cats T	**-0.808**	<0.1	<0.1
Skin Twitching T	**0.719**	<0.1	<0.1
Head Shaking T	**0.487**	**0.484**	<0.1
Play Interaction with Humans T	<0.1	**0.85**	<0.1
Tail Erected T	<0.1	**0.635**	<0.1
Long Lasting Hiding T	0.471	**0.525**	<0.1
Hissing T	<0.1	<0.1	**0.881**

Table 8.12: Behaviour variables loadings on the three factors of interest extracted. The factors’ components are highlighted in bold.

There was a significant difference between AF and C group for factor one “irritability” (Mann Whitney U test; U=369, Z=2.296, p=0.022; see Figure 8.7), where the C cats show more irritability than AF cats.

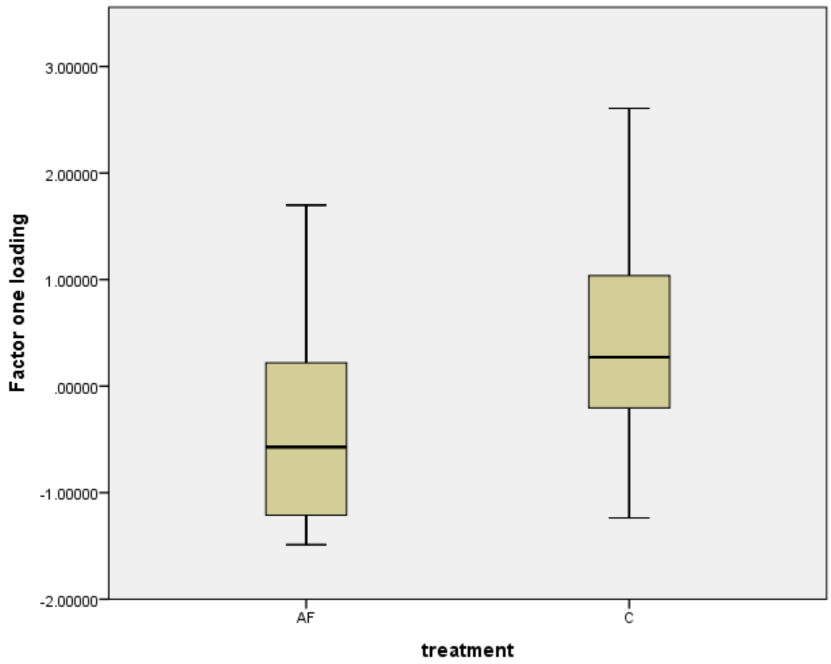

Figure 8.7: Boxplot (mean plus interquartile range) of factor one loading for AF and C group.

Regarding individual behaviours of interest, “scratching people”, “lip licking” and “inappropriate toileting” were selected as they might indicate a negative affective state and “social interaction with human” because it indicates positive interaction with a human. The only significant difference between AF and C group was the behaviour “inappropriate toileting” (Mann Whitney U test; U=189.5, Z=-1.978, p=0.048), where AF cats more often toileted inappropriately than C cats (see Figure 8.8).

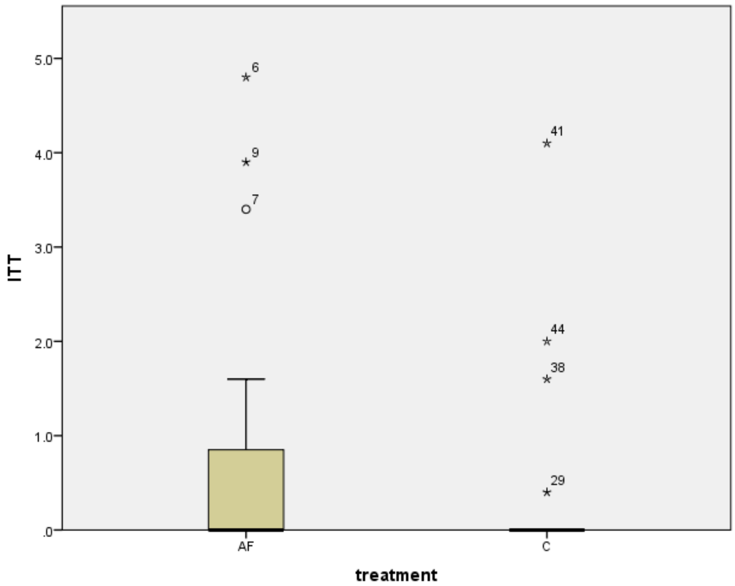

Figure 8.8: Boxplot (mean plus interquartile range) of “inappropriate toileting” frequency for AF and C group.

8.4 Discussion

The aim of the study was to investigate the effects of long-term exposure to an electronic containment system on cat behaviour and welfare by comparing cats who had already been exposed to the system for at least 12 months to those who had no experience of electronic containment. The putative effect on behaviour and welfare was assessed using a variety of approaches including an owner-based questionnaire, cognitive bias and behavioural tests. Relatively few cats completed the cognitive bias tests, so firm conclusions based on a lack of difference are difficult to draw from this test; nonetheless it is clear that cats, compared to dogs (Mendl et al 2010b), require considerably longer training and testing periods. There were also no differences between the groups in the sudden noise test and few differences in the owner survey, unfamiliar person and novel object tests. AF cats interacted more with both the novel object and the unfamiliar person when she was active. This might indicate that the cats with experience of virtual fences were less cautious or that they were more motivated to interact with novelty. Enhanced interaction is generally interpreted as a sign of more positive affective state, suggesting better welfare for contained cats. This is supported by the observation that during phase one of unfamiliar person test, these cats displayed less “lip licking”, which has been associated with anxiety and stress (Podberscek et al. 1991, Van den Bos 1998). It might be expected that being alone with an unfamiliar person is stressful for the cat, but this result might also be (at least in part) the consequence of this being the first of a series of disruptions which make up the series of tests used, so the cat’s response may have been a response to non-specific change rather than a specific response to the presence of the unfamiliar person. Some caution, may be warranted in the interpretation of this result as it was the only significant result of five tests performed for this phase, with $p=0.048$. Nonetheless, if there is an effect it is evidently in favour of the contained cats and this is supported by the results of the latter phases of this test.

Cats have been shown to interact more when a person is active (Mertens and Turner 1988). In the unfamiliar person test, I also predicted that more stressed cats may interact less with the unfamiliar person during phases two and four (i.e. the phases when the unfamiliar person was active without and with the owner present but inactive). In line with the results of phase one; AF cats explored significantly more and interacted more with the stranger. It is possible that these responses are quite specific to unfamiliar people and may reflect differences in sociability between the populations (Finka 2015), since there was no significant difference between the groups in the factors “confidence” or “positive behaviour” derived from the composition of their behaviour in the test and no significant difference outside of phase one in other specific behaviours that may be related to anxiety or conflict such as “lip licking”, “self-grooming” (Van den Bos 1998). It is worth noting that both groups interacted with the stranger and showed greeting and positive affiliative behaviours, indicating that, overall, subjects were not avoidant and probably in a positive affective state.

Regarding the novel object test, AF cats were again less neophobic, exploring the novel object significantly more than C cats. There were no other significant differences between the groups in the display of anxiety or conflict like behaviours, nor in the time spent near the object, suggesting that the observed difference in exploration of the novel object might not be due to a wider difference in trait-level anxiety.

There was no significant difference between groups in the reaction to the sudden noise in any of the recorded measures, indicating that there is no evidence to indicate that the cats exposed to a beep in association with an aversive stimulus (AF cats) were more sensitive to a sudden or high pitched noise. This suggests there was no difference between the groups in vigilance or reactivity that might be associated with anxiety (Grupe and Nitschke 2013), nor evidence of widespread stimulus generalisation, which can occur when an individual is trained to associate a sound with an aversive consequence (Ghirlanda and Enquist 2003). This might, in part, reflect the nature of the study being under field conditions, where external noise could not be completely suppressed, or the difference in location of the test compared to where the warning sound is normally heard (Rescorla and Cunningham 1979). It is worth noting that most of the cats' responses were very mild, e.g. a subtle ear movement and even when there were signs of anxiety or conflict like behaviours, these rarely extended to the animal leaving the feeding area (less than 10% of the cats did leave the feeding area, and not immediately after the noise). This again indicates that the overall anxiety level of cats in both groups was very mild, compared to animals tested in similar conditions (Lansade et al. 2008; Destrez et al. 2014).

The cognitive judgment bias test was used to specifically assess the cats' affective predisposition rather than their response to specific stimuli (Paul et al. 2005; Mendl et al. 2009; Tami et al. 2011). It has been used to infer both positive (Doyle et al. 2010a; Brydges et al. 2011; Briefer et al. 2013) and negative Burman et al. 2008, 2009) affective states. No significant differences were found between the two groups. This is consistent with there being no difference in affective state but, it should be noted that the sample size, for this particular test was small with only 14 out of the 46 cats completing training and testing. The high dropout rate, may reflect the requirement for cats to complete training within a day, since the only previously published study to apply cognitive bias tests to cats (Tami et al. 2011) achieved a much higher success rate (9/11 cats) but used between three and nine days of training for subjects. This latter study examined the feasibility of the protocol used and did not compare populations, but in general, the test does seem to be sensitive, achieving results with small populations in other species (Freymond et al. 2014; Karagiannis et al. 2015).

Overall, the objective behavioural tests indicate that the cats who have experienced extended confinement using an electronic containment system are generally less neophobic than cats not contained in this way and free to roam outside of the property boundaries. This difference might be the result of greater exposure to uncontrolled aversive, such as unfriendly neighbours, negative social interactions or traffic off-site or possibly a population selection bias. Nonetheless there was no evidence of a significant difference between the two populations in neither their affective predisposition nor their tendency to generalise their response to the conditioned stimulus, which have been raised as a potential concern of these systems (CAWC report 2012).

The owner questionnaire indicated that the cat owners recruited for this study have installed the containment electronic system, primarily because they fear for their cat's safety – especially road traffic accidents. I studied 14 items relating to enrichment provision for the cat, and found significant differences only for two items, with most items being provided for all the cats, indicating that the cats in this study were cared for to a high standard, regardless of which group they belonged to. AF owners provided more litter trays and more scratching posts. Although the estimated frequencies of "toileting inappropriately" was very low for both groups of cats, this was reported to occur more frequently amongst AF cats. This might explain the difference in the provision of litter trays, but the reason for the difference in the behaviour is not clear. I did not try to ascertain whether or not the behaviour related to marking or latrine related issues. The former has been associated with general anxiety in cats (Dehasse 1997; Seksel and Lindeman 1998; Mills et al. 2011) whereas the latter relate to more local preferences and aversions with the latrine options provided (Horwitz 1997; Sung and Crowell-Davis 2006; Grigg et al. 2012; Guy et al. 2014). There were no indications from either the behaviour tests or survey to indicate that the cats in the AF group were more anxious and so that the increased prevalence of problem might be related to the emotional consequences of using the electronic containment system. Indeed, it is worth noting that the only owner reported difference in behaviour possibly related to emotionality indicated that the C cats, not the AF cats, showed significantly more irritable behaviour. This might be related to the, on average, higher number of cats in the C households and potential for social tension, although number of cats alone is not a good predictor of the general level of stress of the individuals concerned (Ramos et al. 2013).

The owners were asked to report about the average reaction of their cats over the previous year and the lack of differences between the two populations may reflect little difference in their overall state or a lack of sensitivity of the metric used. It might be that owners do not attend to subtle behaviours, such as "lip licking" "skin twitching" or "head shaking" in response to a novel object or an unfamiliar person or appreciate its potential significance. Although owners have been shown to be able to classify the vocalisation of their own cat, the rate of classification is not very high on average (Ellis et al. 2015), perhaps reflecting a wider lack of attention to potential feline communicative signals. Nonetheless, owner's perceptions can be a useful tool for behaviour analysis in some circumstances (Kendall and Ley 2008), so it is more probable that their perception reflect what happens on average for their cat. One strong finding is that the owner’s perception regarding general anxiety matches the results of most of the behavioural and judgment bias tests where nearly no difference is found between groups regarding potential anxiety/conflict display.

8.5 Conclusion

In this study I recorded a range of different measures, directed both at the cat itself as well as at the cat’s owner, in order to investigate the potential long-term negative impact of an electronic containment system on cats’ behaviour and welfare. Taken together, the findings did not suggest that long-term (at least 12 months) exposure to the system has a significant negative impact on the contained cats’ affective state when compared to uncontained control cats. There was a suggestion of some positive behaviour of contained cats that requires further investigation to ascertain whether it is the influence of the system or just a random finding.

Chapter Nine

General discussion and conclusions

This thesis set out to get a deeper understanding of free roaming cats and their containment. This was done by first investigating people's beliefs about the benefits, risks and problems linked to wandering cats depending on where they live and whether they own a cat or not (Chapter 2). Secondly, by discovering where cats go when they are outside and if they engage in risk taking behaviour like crossing roads (Chapters 3 and 4). Thirdly, by reviewing the risks cats are exposed to when they are outdoors (Chapter 5) and finally, by determining if an electronic containment system has a significant impact on cat welfare (Chapters 6, 7 and 8).

9.1 Outline of findings

9.1.1 People's perceptions about free roaming cats

In relation to these aims it was found that there are important demographic factors shaping people's perceptions of the benefits, risks and problems related to wandering cats, notably where they live and whether or not they own a cat (Chapter 2). Village inhabitants were more interested in pest control and other issues related to wildlife, city inhabitants in the interactions between cats, unwanted litter of cats and disease risk to humans. Cat owners quoted benefits for cats going outside and were concerned for their cats' safety, while non cat owners focused on the risk of disease transmission to humans. Interestingly, I did not find cat owners particularly concerned about the disease risk for cats, despite the fact that they are relatively numerous and some of them have quite serious implications for the cat's health and welfare (Chapter 5). It might be that they are confident in the vaccination, deworming and fighting fleas program they put in place, or that they are not aware of all the risks a cat is exposed to from going outside. Common ground was found in relation to problems such as toileting outside the owner's property and the potential impact of cats on wildlife, and all groups surveyed quoted road traffic accidents as a very high risk. This has important implications for the management of free roaming cats, as getting information about people's perception of a community subject of interest is a way to inform how future policies regarding cats may be enacted in order to get the best results possible (Finkler and Terkel 2012; Uetake et al. 2014; McDonald et al. 2015). The fact that cat owners are aware of the potential impact of cat on wildlife (Chapter 2) and some willing to contain their cat (Toukhsati et al. 2012) in order to reduce this impact suggests, for example, that a policy promoting cat containment, provided that the cat's welfare is ensured, could be well received by cat owners and have associated benefits for local wildlife. Moreover, regarding road traffic accidents, in the UK an estimation of cats' death on roads gave the approximate number 230,000 (based on data from the Pet Plan insurance company). This high number (although estimated), includes only deaths on the road, rather than non-fatal injuries, and so this makes it imperative for cat owners to consider the possibility of cat containment, whether it is confining the cat to the house (indoor lifestyle) or to the owner's property boundary with an effective containment system. Attitudes towards containment have been studied (Toukhsati et al. 2012; Gunaseelan et al. 2013) and cat owners are in support of containment at night and less during the day, speaking of confining the cat in the house (Toukhsati et al. 2012).

9.1.2 Free roaming and risk-taking behaviour of owned, neutered cats

In relation to the second aim of the thesis (i.e. investigating where cats go and whether or not they engage in risk taking behaviours), it was found that the home ranges of cats were not significantly different when comparing a city to a village location, in my particular study (Chapter 4). The average size of home ranges was comparable to those yielded by other studies on owned neutered cats (Hervias et al. 2014; Thomas et al. 2014). However, to my knowledge, this is the first study comparing home ranges of owned neutered domestic cats in two different urban settings (a city and a village) and the lack of difference in home ranges may indicate that the provision of resources by the owners is one essential determinant of the cat's home range and activity (Horn et al. 2011). From this work it is also clear that, regardless of residential location, cats in general travelled great distances (mean distance travelled per day 4 km) and there is great individual variability between cats, which does not seem to be related to local features. Comparing the home range on average to the distance travelled (by theoretically considering the home range a rectangle centred on the home, in order to visualise the distances from home), I found that cats may travel great distances while staying quite close to home, indicating an exploration and maybe regular patrolling of their known, local, environment. This strengthens the hypothesis that cat movement, when a cat is owned, may be determined by resource provision by the owner, leading to the possibility that a modification in the way that resources are provided may be useful as an intervention to modify the roaming behaviour of cats. Regarding the likelihood of road traffic accidents, the GPS use allowed us to determine that cat road crossing behaviour varies greatly between individuals, but that in the study environment most of the cats (10 out of 13) did cross roads on a daily basis, ranging from two to 16 road crossings per day. These findings are in line with a previous study on risk taking behaviour in cats (Loyd et al. 2013) even if in my study more cats crossed roads (76.9% of sample crossing roads in my study versus 45% in Loyd et al. 2013) and more often (80% of cats crossing road doing so at least once a day in my study versus less than 48% in Loyd et al. 2013). Little studied in owned cats, road crossing has been studied in foxes and it was found that they cross roads less than a model of randomly generated fox movement (Baker et al. 2007). In my study, despite having two major roads in the two areas of study, only one cat crossed a major road on a daily basis, and in this instance the entrance of the house was on that major road. This confirms the high risk identified in Chapter 2 of both owners and non-owners of the hazard posed by road traffic to cats and the potential need to protect them from this, as well as the need for more research into this area.

9.1.3 Risk to cats that are allowed outside

However, in order to make practical suggestions that consider the cat's welfare as a whole, it is important not to focus on just one issue, but the wider range of threats to cats and how they can be managed using different management practices. Risks to cats from being allowed outside are diverse and numerous, however they can be mitigated quite successfully up to a point by following a careful program of neutering, vaccination, fighting against fleas and deworming routine. But some specific risks, such as road traffic accidents, getting poisoned or malicious injuries cannot be mitigated successfully unless some kind of containment is put in place. However, keeping the cat indoors also carries risks to its physical (e.g. from environmental toxins) and psychological health (e.g. from frustration). This may lead to changes that threaten the quality of the human cat relationship, e.g. increased aggression or urine marking which can be a cause of relinquishment (Scarlett et al. 1999b). A compromise would be to put in place a type of containment allowing the cat to enjoy the benefits of being allowed outside but to remain inside its owner's property boundaries. However, this is not without its own challenges, as many containment systems for cats appear to be ineffective given their agility.

9.1.4 Welfare of cats exposed to an electronic containment system

I therefore studied a specific containment system that included an aversive event (electric correction), since these are anecdotally reported to be highly effective, and preliminary interviews and a survey (Mahon unpublished data University of Lincoln) indicated that these systems were highly effective, although relatively expensive, but often purchased by owners who had experienced the death of a cat on the road. However, there are concerns over the risk posed to cat welfare by the use of an electrical stimulus in these systems. In order to investigate the potential impact of this containment system on the cats' emotional state, I first gathered initial information on the potential impact with a small case series on four cats that were tested before the installation of the system, short term (10 to15 days) and longer term (10 to 14 weeks) after the installation of the system. Cats showed some potentially meaningful changes (an increased curiosity for the novel object and a mild anxiety) especially in the novel object test around the short term testing that would be consistent with a transitory effect of the system changing the cat's relationship to novelty, but could equally be attributed to random variation. Specifically, two cats showed changes in a different direction. One cat, Indi, seemed to have its 'confidence' boosted by the addition of space according to its owner. The other cat (Jazz) seemed to become more 'irritable' over time according to its owner; an observation that may indicate that the system in this case had a negative effect. However, in this particular case the potential conflict with the other cat of the house did increase in the same time (the other cat just reaching adult age and seemed to seek contact with Jazz more often) and the system was used to prevent it to access the neighbour's garden, so different circumstances altogether may result in a cat being less tolerant. However, there was no evidence of this change feeding through to a change in more robust measures of welfare such as a judgment bias test, the three cats that performed the test showing changes only in the direction of an increased optimism.

This small case series acted as an important prelude to a more controlled study on a more readily accessible population, that focused on the welfare of cats who were already living with and had been exposed to the system for a long time, more than 12 months, compared to cats with no such exposure and who were free to roam (23 cats exposed to the electronic containment system, 23 cats free to roam with no exposure to any containment system). This study showed that cats living with the system interacted more with the unfamiliar person, explored more the novel object than control cats, which may indicate that being contained to a specific safe area may stimulate the cat's will to explore all novelty, but also that the relationship between cat and owner may be different, as the contained cat may be more available when owners want to interact. However, I did not find any difference between groups in the time owners interacted with their cats, at least in the owners' own perceptions. The noise test and the cognitive bias test did not show any difference between groups, while the owner's perception of cat behaviour did not show differences in behaviour related to anxiety/conflict with the possible exception of inappropriate toileting, and this was more common among cats living with a fence. However, it should be noted that overall values of this behaviour were very low, indicating that the typical frequency of inappropriate toileting in the last year was less than once a month, and this behaviour may also relate to population differences rather than the presence of a fence. For example the people investing in a fence system may have a different relationship with their cat, which might increase the risk of this behaviour. Nonetheless further investigation of this association would be useful.

9.1.5 Study findings conclusions

The findings showed that although many of people's perceptions about free roaming cats depends on their residential location and their ownership status, the risk of road traffic accidents is rated highly as a concern by all groups. This perception is matched by the behaviour of free roaming cats, who, regardless of their home location frequently engage in risky behaviour like crossing roads on a daily basis. This represents a high risk to their wellbeing and, combined with the other risks posed to a cat who goes outside, makes a clear case for the need to restrict the cat's roaming behaviour , in order to protect its welfare. Given the problems of an indoor only lifestyle, which are perhaps greater than is widely recognised, there is a case for examining the impact of an effective containment system (that would restrict the cat to the boundaries of its owner's property) on the welfare of the animals so contained. The options for this are limited and little known about their impact. Therefore I examined the impact of an electronic containment system which is widely thought to be effective but also which causes some concern regarding its impact on cat welfare. This was the first research on this system in cats, and I sought to establish if the welfare concerns were justified and outweighed by the potential benefits. The initial case series failed to establish clear evidence of consistent harm and so I carried out a more controlled study into the long term effect of an electronic containment system on the cat's welfare. The population studied were generally very well cared for, and I found no evidence consistent with a long term negative impact of the electronic containment system on cat behaviour and welfare. Indeed cats contained by the system interacted more with people, were more curious about novel objects and no more sensitive to sudden noise than control cats. Whether these effects are due to the system or selection bias in the volunteers remains unknown. Although many research questions have been addressed, there are unanswered questions and directions for future research have been identified.

9.2 Future directions

9.2.1 People's perceptions about free roaming cats

One aspect that my study did not take into account regarding people's perceptions about free roaming cats was the socio-economic profile of the two surveyed populations. Socio-economic and demographics factors may influence people's perceptions (McDonald et al.

2015) and to understand better the relationship between free roaming cats and the society they are living in, I need to be able to determine all the factors that may influence their perception, in order to be able to put in place targeted policies and raise awareness about cat welfare. In my study, city inhabitants of the surveyed zone were very variable: some of them having difficulty speaking English while others were fluent and long established in the area. Students were also more common in the city sample. The village inhabitants were, for the most part, long established residents in the village and might be expected to have a higher income than the city inhabitants that were surveyed. To explore further the potential socio-economic influence on people's perception, one addition to the experiment would be to get much demographic and socio-economic information and to take it into account in the analysis of the data, comparing socio-economic categories rather than type of housing. One other possible experiment would be to match the type of housing (as they are zones in the city with large houses and gardens) and survey the two zones simultaneously to be able to compare those results with my current results. This way I would be able to determine how the factors (socio economic factor and type of housing) respectively influence people's perceptions about free roaming cats.

9.2.2 Free roaming and risk taking behaviour of owned, neutered cats

Cats being involved in road traffic accidents are a very important issue that have both physical (for the cat), psychological (for the cat and the owner; Rochlitz 2004) and economic consequences. Those consequences have not been fully studied. The number of cats killed on the road is unclear as the only number available for the UK is an estimate based on insurance claims for one company. While this is useful information, the number could be refined and more information is needed not only on fatalities on roads per year, but also on cats that are injured (non-fatal) on the roads because quality of life of the cat can be greatly decreased when dealing with the consequences of a road traffic accident. This issue could be addressed with a national survey involving owners, veterinarians and city councils, as this is an important welfare issue for the cat. Gaining information about this number, and also about the distribution of road traffic accidents involving cats, and their prevalence depending on the location, would allow a more balanced debate about the potential need to contain cats to their owner's property.

Moreover, little information is available about cat behaviour around roads, how they cross, whether they evaluate the risks, the variability of the behaviour or the occurrence of particular patterns of behaviour in relation to traffic and road crossing. Gathering information on this matter, together with information on the distribution on road traffic accidents, would allow us to the build a risk analysis model for "road traffic accidents involving a cat". This would help identify potential danger spots for new potential residents in an area which might inform their decisions about cat ownership and management. To explore the matter further, a study involving cat borne cameras and trap cameras at previously determined "crossing sites" could help get an insight on cat behaviour around roads. About risks factors predisposing cats to road traffic accident, in the UK there is one study carried out by Irene Rochlitz based on a questionnaire in veterinary clinics in the Cambridgeshire (Rochlitz 2003a, b). Yet, most of the cats that are found dead on roads would not necessarily be taken to veterinary clinics, so the information about those cats is missing and could greatly influence the risks factors to take in consideration. Moreover the questionnaires were distributed only in veterinary clinics. One way of exploring the matter further would be to be to design a questionnaire that would be more widely distributed, including veterinary clinics but also owners from all counties in the UK to investigate if those risks factors are the same depending on the regions.

9.2.3 Welfare of cats exposed to an electronic containment system

This study is the first study to focus on the impact of an electronic containment system on a species, and especially the long term effect of this system on cats. But many questions remained unanswered. In order to get a more complete view of the potential impact of an electronic containment system on cat welfare, some hypotheses are very important to test. I showed that the average home range of owned, neutered free-roaming cats was around two hectares. Most owners do not have properties that are of this size. In my study, only one owner had a contained area exceeding two hectares, and all of the cats studied in this work had more than 100 m^2 available in their outside space. This is not a small area. It might be that there is a minimum size below which the mechanism of containment has a detectable impact on the welfare of the cat, since they may be more likely to receive warning alarms more frequently in smaller areas. It would thus be useful to examine if the size of the area contained with an electronic containment system has an impact on the welfare of the cats, with a particular focus on smaller gardens. The same methodologies could be used: the novel object test, the noise test and the cognitive bias test, alongside the use of modified collars on cats that would measure the number of warning alarms and electrical impulses delivered. This latter methodology was piloted in the homes studied here but was not part of my PhD work, and so is not documented here.

The case series (Chapter 7) suggested that cats might react differently according to the way in which the fence is installed. For example, when it is used to prevent a cat from going somewhere that they previously might have been highly motivated to go, it may be liable to cause more frustration. It would therefore be important to test the hypothesis regarding the influence of previous experience: is there a difference between a cat that was kept indoors before the installation of the containment system (and had never experienced the ability to free-roam in that particular locality), and a cat that has had its usual home range markedly reduced or altered significantly in some way (i.e. was allowed to free-roam in the locality prior to containment)? The same methodologies could be used, focusing on recruiting cats of the two categories (i.e. indoor before installation, or free roaming before installation) to compare their responses, but it is accepted recruitment for such a study is likely to be a major logistical challenge as was the case in the case series. In my GPS study, I established that provision of resources may be an important parameter influencing the roaming's behaviour of the cats. In order to improve the contained cats' welfare, I could investigate if the type and amount of resources provided to the cat, both inside and outside the house, have an influence on the risks taken by cats and their welfare when contained. In ewe lambs, naive lambs may encourage trained lambs to cross an electronic containment system boundary (Jouven et al. 2012). Although cats are not considered to be a social species, at least not to the same extent as sheep, specific relationships between two conspecifics living together may have consequences. The relationship between cats of the same household may also influence their relationship with the containment system. Two or more cats would have to share the same space with no possibility of leaving the property. Or, one cat could influence another cat's tendency to cross the boundary. In order to investigate this matter, the same methods would be used focusing on the difference between single and multi-cat households. Finally, regarding the early phase of the system's installation, I was able to test only four cats during this crucial phase of reaction to the containment system. Recruiting more cats would allow us to be able to analyse the findings as a group and compare them to a control group. However, such a study may prove challenging as recruitment of people about to install the system is very difficult (due to the relatively small number of new installations over time). My recruitment went on for 10 months and yet I was still only able to recruit four cats in this category.

9.3 Final conclusions

Cat owners are legally responsible for the welfare of their cat, and if they want to avoid neighbourhood conflict or malicious injuries to their cat, they need to be aware of the problems their cats might cause to the local community. People's perceptions on benefits, risks and problems linked to free roaming cats depend on their residential location and ownership status but there are also shared views in some matters. Owners are aware of the potential impact of their cat on wildlife and of the problem of soiling other properties. Moreover, all groups quoted "road traffic accident" as the greatest risk to cats allowed to roam. This perception is matched by the risk taking behaviour of cats, which, even though they may stay close to home, cross roads often. This risk, alongside the other risks posed to cats that go outside, make the proposal to contain a cat, at least to its owner's property, seem reasonable. However, being contained, even when food, water and shelter are provided for, is not without its risks. I did not find significant evidence of welfare compromise among cats that were exposed to an electronic containment system for more than 12 months. The cats were well cared for and that the space allowed was larger than 100 m^2 and any of these factors independent of or in combination with the containment system, might explain the good welfare observed. Further research is warranted to explore the effect of a containment system in more diverse situations, but it is clear that these systems are not *necessarily* harmful as has been claimed by some, prior to the generation of scientific evidence on this matter, which has formed the basis of this thesis.

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Appendices

Appendix one

UNIVERSITY OF LINCOLN

THIS IS NOT A CIRCULAR

Dear Resident,

Your area has been chosen for a survey about your community being undertaken by researchers from the University of Lincoln. Please help us with this work.

It is very important for us to get as many people as possible to reply to this survey, in order to get an accurate view of things **even if it is just to establish that you have no interest in the subject.**

Please note that your answers are confidential and will be treated anonymously.

The aim of the study is to examine your opinion of cats in the community. Please give us a few minutes of your time to answer a small number of questions. It should take less than ten minutes of your time and we will really appreciate your help. The questionnaire has to be completed by an adult in the household (if you own a cat this should be the adult taking care of the cat). You can either write your answer down and use the prepaid reply envelope, or you can do the survey online http://www.surveymonkey.com/s/8G7DTWL

If we haven't heard from you within three weeks, a researcher will pop by to collect the survey from you or to answer any questions you may have before you complete it. The researcher will identify him/herself with his/her university ID and if you have any questions you can contact the project leader: Prof. Daniel Mills

dsmills@lincoln.ac.uk

We would like to thank you for your cooperation in advance.

Yours sincerely,

Dr Naïma Kasbaoui and Kevin Mahon.

Please state your address. We need this in order to recognise that you have answered the survey.

Please indicate how long you have lived at this address

____________________Year(s)________________________Month(s)

Do you consider yourself to be a « cat lover » ?

☐ Yes

☐ No

☐ Not sure

Do you own a cat ?

☐ Yes

☐ No

If Yes, please go to section B.

If No, please answer the following question.

Have you owned a cat during the time you have lived at this address ?

☐ Yes

☐ No

If Yes, please go to section B

If No, please go to section A

SECTION A : PEOPLE WHO DO NOT OWN A CAT

A01. How often do you see cats visiting your property (including any garden you may have) ?

☐ More than once a day

☐ Once a day

☐ Once a week

☐ Less than once a week

☐ Less than once a month

☐ Never

A02. How many times in the last week have you seen cats wandering in your neighbourhood ?

☐ More than 10 times

☐ 5-10 times

☐ 2-5 times

☐ Once

☐ Never

Please answer the four following questions (A03 to A06) with regards to cats in general :

A03. In your opinion, what are the **two most important benefits** to a cat from being allowed to go outside ?

☐ I think there are no benefits to a cat from being allowed to go outside.

☐ Freedom to express natural behaviour

☐ Opportunities to hunt

☐ Exercise

☐ Interactions with humans

☐ Interactions with other cats

☐ Interactions with other animals

☐ Interesting experiences for the cat

☐ Other, please specify :

A04. In your opinion, what are the **three main risks to cats** from being allowed to go outside ?

☐ Road traffic accident

☐ Problematic encounters with others animals (including being chased out of their property)

☐ Problematic encounters with humans

☐ Disease risk

☐ Being Poisoned

☐ Getting lost

☐ Being stolen

☐ Other, please specify:

The following two questions relate to the impact of cats on the community rather than just you

A05. In your opinion, what are the **two most important benefits** for the community of cats in the neighbourhood ?

☐ I think there are no benefits to the community from cats in the neighbourhood

☐ Pest control

☐ Acts as a focus for neighbourhood interaction (e.g. chatting about the cats' behaviour)

☐ Provides enjoyment for those who like cats

☐ Helps people learn about certain aspects of nature

☐ Provides a source of routine to people's life

☐ Gives people something special to care for

☐ Other, please specify :

A06. In your opinion, what are the **three main problems** for the community of cats in the neighbourhood ?

☐ Unwanted litters of cats

☐ Disease risk to humans

☐ Human being bitten by a wandering cat

☐ Upsetting other cats

☐ Unwanted toileting/spraying

☐ Damage to property

☐ Leaving dead/injured prey items (e.g. birds, rodents)

☐ Others sources of neighbourhood conflicts

☐ Killing wildlife (i.e. birds, rodents)

☐ Cats making a lot of noise

☐ Other please specify :

Please answer the two following questions (A07 and A08) with regard to your personal experience :

A07. Since living here, have you experienced any benefits linked to cats in your neighbourhood ?(please tick all that apply)

☐ I haven't experienced any benefits linked to cats wandering in my neighbourhood

☐ Pest control

☐ Acts as a focus for neighbourhood interaction (e.g. chatting about the cats' behaviour)

☐ Provides enjoyment for those who like cats

☐ Helps people learn about certain aspects of nature

☐ Provides a source of routine to people's life

☐ Gives people something special to care for

☐ Other, please specify :

A08. Since living here, have you experienced any problems linked to cats in your neighbourhood ? (please tick all that apply)

- ☐ I haven't experienced any problems linked to cats wandering in my neighbourhood
- ☐ Disease caused by cats
- ☐ Cat bites
- ☐ Cat(s) upsetting your pets
- ☐ Cat(s) toileting/spraying on your property
- ☐ Damage to your property
- ☐ Other source of neighbourhood conflict
- ☐ Wildlife killed on your property
- ☐ Dead/dying prey items (e.g. birds, rodents) left on your property
- ☐ Cats making a lot of noise
- ☐ Other, please specify :

Thank you very much for answering to this survey, your contribution is very valuable to us.

SECTION B : CURRENT OR PREVIOUS CAT OWNER

If you consider yourself as a "multicat" household please tick here : ☐
If you own or have owned several cats, please answer for the cat you have owned <u>for the longest time at the current address</u>, unless the question indicates otherwise.

B00. Since moving to your current address, for how long have you owned your cat ?

_____________ Year(s) _____________ Month(s)

B01. Is your cat :

☐ Male

☐ Female

B02. Is your cat neutered ?

☐ Yes

☐ No

B03. Does your cat have access to the outside and if so, when ? (tick as relevant)
☐ My cat doesn't have access outside
☐ Day and night

☐ All day only

☐ All night only

☐ Few hours during the day, please state an average time per day : Hour(s)

☐ Few hours at night, please state a average time per night : Hour(s)

B04. Do you do anything to prevent your cat from roaming beyond your property boundaries (tick all that apply) ?
☐ I don't do anything to contain my cat

☐ I keep my cat indoors

☐ My cat has a supervised access outdoor (e.g. I put him/her on a leash or I watch him/her)

☐ I have high fences

☐ I have an electronic containment system (e.g. Freedom fence®, Invisible fence®)

☐ I have specific « cat-proof » fencing (such as those shown in the images below) :

image credit to cat secure®, purrfect fence®

☐ I have another specific containment system, please specify :

B05. If allowed to go outside your property, do you think your cat visits other properties ?

☐ Yes, all the time

☐ Yes, sometimes

☐ No

☐ Not sure

B06. Do you think anyone else feeds or looks after your cat when he/she is outside ?

☐ Yes

☐ No

☐ Not sure

B07. Do other cats visit your property ?

☐ Yes

☐ No they don't visit the property (i.e. I don't see them)

☐ No they can't visit the property (e.g. I live on a top floor flat)

B08. Do you feed or look after any cats that visit your property ?

☐ Yes

☐ No I don't feed any cat that visits my property (I choose not to)

☐ No because cats don't visit my property

B09. How many times in the last week have you seen cats wandering in your neighbourhood ?

☐ More than 10 times

☐ 5-10 times

☐ 2-5 times

☐ Once

☐ Never

Please answer the four following questions (B10 to B13) with regard to cats in general :

B10. In your opinion, what are the **two most important benefits** to a cat from being allowed to go outside ?

☐ I think there are no benefits to a cat from being allowed to go outside

☐ Freedom to express natural behaviour

☐ Opportunities to hunt

☐ Exercise

☐ Interaction with humans

☐ Interactions with other cats

☐ Interaction with other animals

☐ Interesting experiences for the cat

☐ Other, please specify :

B11. In your opinion, what are the **three main risks to cats** from being allowed to go outside ?

☐ Road traffic accident

☐ Problematic encounters with others animals (including being chased out of the property)

☐ Problematic encounters with humans

☐ Disease risk

☐ Being poisoned

☐ Getting lost

☐ Being stolen

☐ Other, please specify :

The following two questions relate to the impact of cats on the community rather than just you

B12. In your opinion, what are the **two most important benefits** for the community of cats in the neighbourhood ?

☐ I think there are no benefits to the community from cats in the neighbourhood

☐ Pest control

☐ Acts as a focus for neighbourhood interaction (e.g. chatting about the cats' behaviour)

☐ Provides enjoyment for those who like cats

☐ Helps people learn about certain aspects of nature

☐ Provides a source of routine to people's life

☐ Gives people something special to care for

☐ Other, please specify :

B13. In your opinion, what are the **three main problems** for the community of cats in the neighbourhood ?

☐ Unwanted litters of cats

☐ Disease risk to humans

☐ Human being bitten by a wandering cat

☐ Upsetting other cats

☐ Unwanted toileting/spraying

☐ Damage to property

☐ Leaving dead/injured prey items (e.g. birds, rodents)

☐ Other source of neighbourhood conflicts

☐ Killing wildlife (i.e. Birds, rodents)

☐ Cats making a lot of noise

☐ Other, please specify :

Please answer the following question with regard to your personal experience :

B14. Since living here, have you experienced any benefits linked to cats in your neighbourhood ?(please tick all that apply)

☐ I haven't experienced any benefits linked to cats wandering in my neighbourhood

☐ Pest control

☐ Acts as a focus for neighbourhood interaction (e.g. chatting about the cats' behaviour)

☐ Provides enjoyment for those who like cats

☐ Helps people learn about certain aspects of nature

☐ Provides a source of routine to people's life

☐ Gives people something special to care for

☐ Other, please specify :

B15. Since living here, have you experienced any problems linked to cats in your neighbourhood ? (please tick all that apply)

- ☐ I haven't experienced any problems linked to cats wandering in my neighbourhood
- ☐ Disease caused by cats
- ☐ Cat bites
- ☐ Cat upsetting your pets
- ☐ Cat toileting/spraying on your property
- ☐ Damage to your property
- ☐ Other source of neighbourhood conflict
- ☐ Wildlife killed on your property
- ☐ Dead/dying prey items(e.g. birds, rodents) left on your property
- ☐ Cats making a lot of noise
- ☐ Other, please specify :

Please answer the three following questions (B16 to B19) with regard to ANY OF YOUR cats :

B16. Since living here, have any of your cats experienced any benefits associated with being allowed to go outside ? (please tick all that apply)

- ☐ My cat never goes outside
- ☐ Express additional natural behaviour
- ☐ Hunt
- ☐ Exercise
- ☐ Interaction with humans
- ☐ Interaction with other cats
- ☐ Interaction with other animals
- ☐ Interesting experiences for the cat
- ☐ Other, please specify :

B17. Since living here, have any of your cats experienced any problems associated with going outside ? (please tick all that apply)

☐ My cat never goes outside

☐ Road traffic accident

☐ Problematic encounters with others animals (including being chased out of the property)

☐ Problematic encounters with humans

☐ Disease risk

☐ Being poisoned

☐ Getting lost

☐ Being stolen

☐ Unwanted mating

☐ Other, please specify :

B18. Since living here, have any of your cats been accused of any of the following problems associated with going outside ? (please tick all that apply)

☐ My cat never goes outside

☐ My cat has never been accused of any problems

☐ Causing disease to humans (worms, infections, cat bites)

☐ Biting humans when outside

☐ Upsetting other cats

☐ Toileting/spraying

☐ Damage to other people's property

☐ Leaving dead/dying prey items in other properties

☐ Other source of neighbourhood conflicts

☐ Killing wildlife (i.e. birds, rodents)

☐ Making a lot of noise

☐ Other, please specify :

B19. If your cat is allowed to go outside, would you be interested in helping us to learn more about where your cat goes and what he/she gets up to ?
☐Yes
☐No

If Yes, please give contact details in the space below and we will be in touch.

Thank you very much for answering the survey, your contribution is very valuable to us.

If you want to get more information about cats in the community and maybe participate in a national survey, please visit the link http://cats.blogs.lincoln.ac.uk/

Appendix 2

List of criteria to include or exclude a cat from the study

The study will **include**:

Cats from one year to fifteen years of age. At one year cats are considered to be mature enough to take part in the study and after fifteen years they are more likely to experience health problems or discomfort, which would interfere with the quality of the data obtained

Cats of any breed or type, male or female, but neutered.

Owners using commercially branded equipment from a reputable company known to the researchers, installed by the company, and currently following the company guidelines regarding the collar's use.

Cats that are in general good health and not receiving any long term health or behaviour treatment. If the cat has been or is receiving short term treatment, each case will be assessed individually to see if the cat can be included in the study. These data will also be collected in order to evaluate the prevalence of these problems in this population compared to a control group.

For people who already have an electronic containment system installed, the system has to have been installed for more than one year.

The study will **exclude**:

Volunteers from Wales

Entire cats

Lactating female cats and those with kittens younger than two months old.

Cats that have always been very apprehensive, i.e. before the system's installation (that hide when someone comes to the home and stay hidden until long after the person is gone)

Cats that don't tolerate being touched or handled in any way, as in these circumstances handling may cause stress.

Households that went through big changes in lifestyle in the three months before the study begins, e.g. moving house, moving a lot of furniture, having work done in the house (like building a conservatory, redecorating, painting rooms), changes in the household like arrival of a new baby, a new person moving in. Each case can be individually assessed.

Information about the study

Dear Sir/Madam,

Thank you very much for volunteering to participate in our study. We would like you to read carefully this description of the study before signing the consent form.

We would like your cat to take part in several behavioural tests in order to assess its reaction to novelty and unfamiliarity as well as its general mood, in order to assess the effect of having lived with an electronic containment system for more than one year. There will be four behavioural tests in total, distributed over two days, involving two visits, each visit lasting approximately one hour per cat. The first three tests are relatively short and will be performed on the first day, along with filling in a questionnaire about your cat.. The fourth test may take a bit longer and so will take place on the second day.

These behavioural tests are not harmful, and are based on events that your cat would typically experience in its daily life.

We would also like to put some cameras within the boundaries of your properties in order to film your cat's behaviour around those boundaries. These cameras are triggered by motion and will record any movement near the ground within a 20 metre distance. The cameras would be set only to film the fence boundaries.

Finally we would like your cat to wear a collar that would record its activity during three usual days, this is an adapted but functional version of the collar your cat normally wears.

BEHAVIOURAL TESTS SCHEDULE (FOUR TESTS)

FIRST DAY OF TESTING

The cat has to be inside before we start the tests, in a room where he/she can't see the main access point to the house (e.g. front door), so the researcher can come in without being seen by the cat. This is only necessary for the first test.

The first test is the 'unfamiliar person' test:

The purpose is to test your cat in an environment that is familiar and comfortable to him/her, and to present a person that is not familiar to him/her (i.e. the researcher). We also want to take into account the effect of your presence, so the test is divided into four phases, each phase lasting two minutes:

- In the first phase, the cat is alone with the researcher who stays stationary in one place, and records how long it takes your cat to approach them.
- In the second phase, the experimenter calls the cat's name every 30s to try to attract its attention.

In the third and the fourth phase, you (the owner) are involved. We would like you to come in when the researcher gives a signal, to sit at a pre-determined place (decided with the researcher before the start of the test), to have your hands on your knees and to have no eye contact with your cat.

- In the third phase, both the owner (you) and the researcher stay immobile and let the cat move around them.
- In the fourth phase, the owner stays immobile and in the same position, while the researcher starts to call the name of the cat every 30s to try and attract its attention.

Your very important role in this test is to introduce the cat gently into the chosen room at the beginning of the test, and to come in to the room when the researcher gives the signal, and to sit still for four minutes in total.

The test will be video recorded which will allow us to observe the behaviours that your cat exhibits, like whether or not it meows, the time that he/she spends close to us, and/or interacting with us.

In order to perform this test, you have to choose a room that has no direct access to outside, and where two people can sit at least two metres apart from each other, e.g. the living-room. The cat must have free access to that room on a regular basis so that it is fully relaxed. For example, if your cat is not allowed in a specific room, this room shouldn't be chosen.

The second test is the 'novel object' test:

The purpose of this test is to observe your cat's reaction to a novel object (i.e. something that he/she has never met before) during three minutes. Some measures, for example the number of approaches, or if he/she rubs on the object or sniffs it, will be recorded. In the same room as for the 'unfamiliar person' test, the researcher will put an object in direct view from the door, at a set distance. On the researcher's signal, you will gently introduce the cat in the room and close the door. The test will last three minutes.

The third test is the distractibility test:

The purpose is to observe your cat's reaction to an unexpected sound when he/she is eating. So, the test will be carried out where you usually feed your cat, and the researcher will position speakers and a laptop near to where the food bowl is located. Your cat will be allowed into the room for one minute in order to get familiarised with the speakers and the computer. Then a few treats (or usual food depending on your cat's diet) will be put in the food bowl so the cat can eat in a relaxed way. Once familiarisation is completed (i.e. the cat appears relaxed and has eaten the treats from the bowl), more treats or food will be put in the food bowl and the test itself will begin. Your cat will be allowed in the room, and after five seconds of eating, a noise will be played. Your cat's reactions to this noise (e.g. ear movement, gaze towards the speakers) will be recorded for one and a half minute. The noise is not designed to be so loud or scary, so as to upset your cat.

Questionnaire:

After the test, the researcher will give you a questionnaire to fill in, with questions about your cat, its behaviour and also the electronic containment system. The researcher will be available should you have any question about your cat, the questionnaire or any of the tests.

Overall, the visit on the first day shouldn't last more than one hour per cat.

Typical schedule of the day

Unfamiliar person test 15 min	Novel object test 10 min	Distraction test 10 min	Filling in questionnaire 10-20 min

SECOND DAY OF TESTING

We would like to discuss with you where it would be best to put the cameras before starting the test with your cat. Once the camera position is agreed, one researcher will set them up while the second researcher will test the cat in your presence. This way, the length of the visit will be kept to a minimum.

The test on the second day is designed to assess your cat's general mood. It is a test that requires training and involves food, so **it is very important that either we perform the test before your cat's normal meal, or the usual amount of food that you give to your cat is reduced before the test.** The purpose is that your cat will be motivated by food (which it will get during the test itself).

Cognitive bias test:

Research in humans and animals has demonstrated that our mood can influence the way we perceive what is around us, especially things that are ambiguous. In this way, a person that is anxious will be "pessimistic" and someone that is feeling good will be "optimistic". For example, you are driving home, and an unknown car is parked in your driveway. If you had a very bad day, you may think "someone is burgling my house!" while if your day was very good and you are in a positive mood, you may think "surely a friend has popped by with their new car!".

The kind of test that we will do with your cat is designed to give us that sort of information, based on how they respond to something ambiguous.

This test consists of presenting a bowl of food in a defined area (the area is defined by an enclosure of 25 cm high), and training the cat to go to a food bowl only when that bowl is placed a particular location. For example, we might train your cat to go to the food bowl when the bowl is placed on the left side of the enclosure (to gain a food reward), but to ignore the bowl if it is placed on the right side (no food reward). So, at the end of the training, your cat should know that if the food bowl is on the left, there is food available, but when it is on the right, the food is not accessible. Once this has been learned, then we can test how your cat responds to something ambiguous – the food bowl being placed in a new location.

The test consists of putting the food bowl in a position the cat has never encountered before (e.g. in the middle of the enclosure) and then recording its reaction. Will he/she run to the food bowl as though they think it will contain food (i.e. 'optimistic'), or will he/she ignore the bowl as they think that it will be empty (i.e. 'pessimistic')?

Of course, one single test does not allow us to determine the mood of an animal absolutely, but it does give us useful information to add to the behaviours recorded in all the other tests.

Exploring the cat-fence interactions: in-line monitoring

An important element of this study is the gathering of information related to how your cat learns to restrict his/her movements to within the containment boundary.

Clearly, one of the main concerns for cat owners is the number of corrections that are needed for the avoidance response to be successfully maintained. We would thus like to fit your cat with a modified collar which is able to capture a considerable amount of useful data, monitoring his movements within the containment boundary, along with the number and type of stimuli that he experiences. This collar is compatible with all major electronic containment systems. These collars will function normally and be capable of recording the number of auditory and visual stimuli issued, as well as tri-axial accelerometer data. We would like your cat to wear the collar for three typical days when he/she can go out, the idea being to fit the modified collar instead of the usual collar, and that your cat carries on its activities as usual.

And in order to gain a complete profile of your cat´s responses, we would like to fit trail cameras (the type used to capture pictures of wildlife without people) along the perimeters of the electronic containment system boundaries, so we can record your cat's behaviour around the fence. The cameras would stay in place for three days as well, so it will allow us to pair data from the collar with video footage.

Overall, the visit on the second day shouldn't last more than one hour per cat.

Typical schedule of the day

Installing trail cameras	Cognitive bias test 45 mn, then give modified collar and answer any questions

If you have any questions and/or are interested about the study you can contact Dr Naima Kasbaoui and Dr Marta Gil at nkasbaoui@lincoln.ac.uk or mgil@lincoln.ac.uk or arrange a telephone discussion.

Kind regards,

Dr Naima Kasbaoui DVM MSc and Dr Marta Gil MSc PhD

Animal Behaviour and Welfare Group
University of Lincoln
Riseholme Park Campus
Lincoln LN2 2LG

Appendix 3

Owner consent form

Study title: Assessing the welfare of a cat exposed to an electronic containment system.

Researchers' details

Name: Dr Naima Kasbaoui
Email: nkasbaoui@lincoln.ac.uk
Phone: 07 582 572 631

Name: Dr Marta Gil
Email: mgil@lincoln.ac.uk
Phone: 07 847 879 495

Description of the study:

The study aims to assess the emotional state of your cat, i.e. how it feels in general, , and to monitor its reaction to the fence by wearing a modified collar that records any cat/fence interactions and setting up cameras that will record its behaviour around the fence. This information will help us to determine the impact of containment on cat welfare.

The study consists of direct behavioural observations of your cat(s), by the researcher and by means of trail cameras, and collection of data by means of a modified collar. It consists of four behavioural tests: an 'unfamiliar person' test, a 'novel object' test, a 'distraction' test and a 'cognitive bias' test. The cognitive bias test requires some training of your cat and so, for this reason, the cat needs to be hungry at the time of the testing. Ideally we are able to carry out the 'cognitive bias' test before you give your cats its normal meal. All the behaviour tests will take place in your home, at a convenient time, and will take approximately one hour per cat per day, for two consecutive days. We will also ask you to fill in a questionnaire about your cat, its behaviour and your rationale to install the electronic containment system. We will be available whilst you fill out the questionnaire to help explain the questions.

At the end of the two days we will deliver to you the modified collar to be worn by your cat for three consecutive days and set up some cameras along the perimeter of the electronic boundaries for the same number of days. .

Schedule of the days:

Day one:

Unfamiliar person test 15 min	Novel object test 10 min	Distraction test 10 min	Filling in questionnaire 10-20 min

Day two:

Installing trail cameras	Cognitive bias test 45 mn, then give modified collar and answer any questions

Please read the following statements carefully:

I have read the description of the study MNUL.

I understand that it is possible to withdraw my cat(s) from this study at any time, without needing to give notice or reason, and that I may ask for the associated data to be destroyed.

I agree that my cat(s) taking part in this study may be photographed and/or filmed for the duration of the study, in order to assist with data collection. (All material will be stored confidentially following the study unless permission given otherwise as indicated below.)

Videos and photographs collected in the course of our research can be valuable educational material and help in the publication and communication of our work. In this instance, the information is anonymised as far as reasonably possible.

☐ Please tick here if you agree that videos or photographs of your cat(s) may be used for purposes outside of this study as described above

I have read and understood the above statements and consent to my cat(s) taking part in the study.

Owner's name ______________________________

Signature ______________________________ **Date** ________________

Researcher's name ______________________________

Signature ______________________________ **Date** ________________

Researcher's name ______________________________

Signature ______________________________ **Date** ________________

Please complete the following:

Your details

Name:		
Address:		
Email:		
Phone:		
Preferred contact method (delete as appropriate):		**Letter / Email / Phone**

Your cat's details

Cat 1		**Cat 2**	
Name:		**Name:**	
Age:		**Age:**	
Sex:		**Sex:**	
Breed:		**Breed:**	

Cat 3		**Cat 4**	
Name:		**Name:**	
Age:		**Age:**	
Sex:		**Sex:**	
Breed:		**Breed:**	

If you have additional cats please list their details at the bottom of this form or attach another sheet of paper

Appendix 4

UNIVERSITY OF
LINCOLN

Dear Sir/Madam,

Thank you very much for volunteering to take part in our study. This study is being undertaken by researchers at the University of Lincoln to assess the potential effect of containment systems on cat welfare. We would like to perform some simple behavioural tests with your cat to see how he/she responds in different contexts, for example when meeting a new person. These tests, in conjunction with talking to you about your observations of your cat's behaviour (see below), will help us to assess the welfare of your cat. For this reason, your input and the knowledge you have of your cat is very valuable to our study.

This questionnaire should be filled in by the adult who spends most time with the cat, and, when answering the following questionnaire about the behaviour of your cat, please take your time to answer as accurately as possible. Please include all your observations relating to a given question, even if you think that they might not be important – we simply want to try to understand your cat's behaviour.

I will be available to answer any questions that you might have whilst you complete the questionnaire, and can provide you with examples (via photos and video clips) of the key cat behaviours that we are interested in, so please do not hesitate if there is anything that you wish to ask.

We thank you again for your help,

Yours faithfully,

Dr Naima Kasbaoui

Other research team members: Prof D. Mills, Prof J Cooper, Dr O. Burman, Dr Marta Gil

1. **Please give the name of your cat:**

……
…………………………………………………….

2. **Is your cat male or female?**

☐Male

☐Female

3. **Is your cat neutered?**

☐Yes

☐No

4. **If Yes, at what age was it neutered? (if not sure, please indicate this)**

……
…………………………………………………….

5. **Has your cat learned to do any behaviours for a reward? For example…..sitting on command for a treat?**

☐Yes

☐No

6. **Before the installation of the electronic containment fence, did you do anything to contain your cat? (like having high fences, supervised access outdoor, cat-proof fences)**

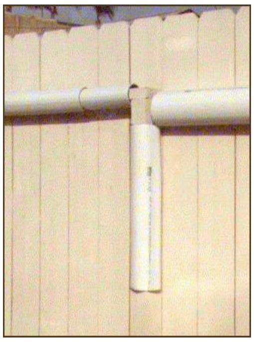
☐I did not do anything to contain my cat

☐I kept my cat indoors

☐My cat had a supervised access outdoors (e.g. I put him/her on a leash or I watch him/her)

☐I have high fences

☐I have specific « cat-proof » fencing (such as those shown in the images below) :



cat secure®, purrfect fence®

☐I have another specific containment system, please specify :

……
……………………………………………………

7. **Could you please state the make and model of the electronic containment system you chose to have installed, and when you had it installed?**

Make: ………

Model: ………

Date of installation: ………………………………………………………………………………………………

Size of the contained area: …………………………………………………………………………………….

8. **Before the electronic containment system installation, what was the level of access your cat had outside? (please tick one of the following, and provide more detail where indicated)**

☐ All day

☐ All night

☐ A few hours a day, please state how many: ……………………………………………………………….

☐A few hours at night, please state how many: ………………………………………………………………

☐ 24/7 access outside (e.g. through a cat flap or living outside)

9. **What was your rationale for installing an electronic containment system?**

………
………
………
………
………
………
………
…………………………………………………………….

10. **How many times, if any, in the last week do you think your cat has received an auditory warning from its collar?**

………
………
………
………
………
………
………
…………………………………………………………….

11. **How many times, if any, in the last week do you think your cat has received an electric stimulation from its collar?**

………
………
………

12. Are there any special places in the contained area you think your cat likes to go?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………….

13. What type of food does your cat eat and at what time in the day? Please state the type of food (dry or wet food, if you know it the brand, and the quantity per meal). If the cat is fed as much as he/she wants, please state the quantity you give him/her per day.

Food type and quantity:
……………………………………………………………………………………….

Time fed:
…………………………………………………………………………………………………
……………………..

Food type and quantity:
……………………………………………………………………………………….

Time fed:
…………………………………………………………………………………………………
……………………..

Food type and quantity:
……………………………………………………………………………………….

Time fed:
…………………………………………………………………………………………………
……………………..

Food type and quantity:
……………………………………………………………………………………….

Time fed:
…………………………………………………………………………………………………
……………………..

14. How much time do you and other members of the family spend interacting with your cat (playing, stroking him or her, sitting together etc) on a typical 24 hours?

☐ Less than 1 hour

☐ 1-2 hours

☐ 2-5 hours

☐ More than 5 hours

15. How much time do you think your cat spends outside over an average 24 hours?

☐ Less than 1 hour

☐ 1-2 hours

☐ 2-5 hours

☐ More than 5 hours

16. **Which of the following do you provide for your cat inside the home? (please tick all that apply)**

☐ Opportunity to exercise beyond normal walking in the house (e.g. play, movable feeding devices)

☐ Access to a spot for sun bathing

☐ Water

☐ Toys

☐ Access to fresh air (e.g. partially opened window)

☐ Food

☐ Litter tray

☐ Specific cat sleeping area

☐ Scratching post

☐ Companionship from other animals

☐ Companionship from humans

☐ Vantage points

☐ Places to hide

☐ Windows to watch outside

☐ Other specific provisions to help keep your cat happy, please give details

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
….

17. **Would you say that your cat is in good health?**

☐ Yes

☐ Not sure

☐ No. Please state the type of problems your cat has:
…………………………………………………………………………………………………
…………………………………………………………………………………………………
………………………………………………………………………………………………..

18. **Would you say that your cat is stressed?**

☐ No

☐ Not sure

☐ Yes. Please state the type of problems your cat has:
…………………………………………………………………………………………………
…………………………………………………………………………………………………
………………………………………………………………………………………………..

19. **Does your cat show any behaviours that you consider to be unusual, abnormal or problematic?**

☐ No

☐ Not sure

☐ Yes . Please give brief details here:

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………..

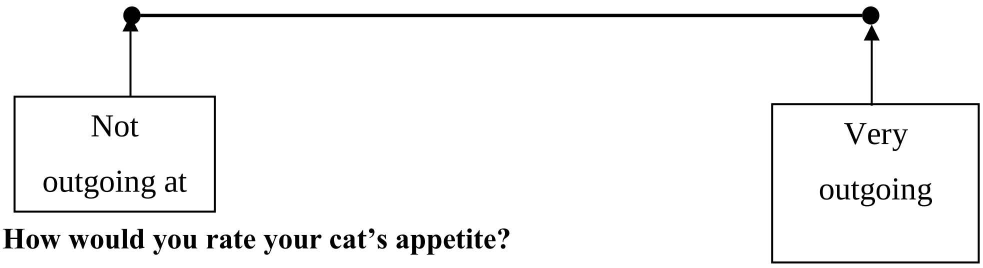
20. **If you had to describe your cat, do you think your cat is (<u>please circle the correct answer)</u>**

Very motivated by food / motivated by food / not very motivated by food / not motivated by food at all.

For the next questions, please put a cross on the line to rate your cat's behaviour and appetite.

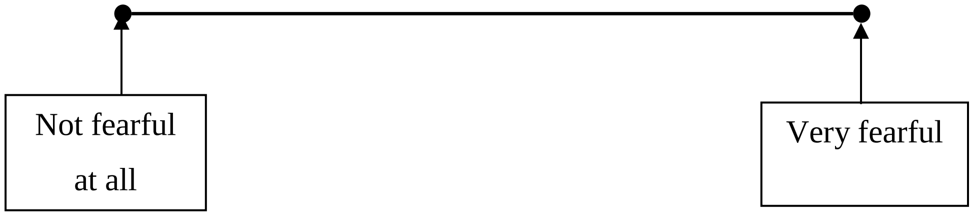
21. **How would you rate your cat's anxiousness?**

22. **Would you say your cat is outgoing/confident?**



23. **How would you rate your cat's appetite?**

24. When a NEW OBJECT is introduced into the house, how does your cat react?



25. When a NEW PERSON comes into your house, how does your cat react?

26. Overall, how well do you think your cat copes with CHANGES (e.g. moving furniture, having some building/maintenance work done at your home, moving house, new people coming round etc.,) Please put a cross on the line below to indicate your response. If your cat has specific events, that it dislikes, please indicate these afterwards

Specific event that your cat dislikes:

……
……
……
……
……
……
……
…………………………………………………………

27. Have there been any significant changes, (including, but not limited to, those examples listed above in question 26) to the household in the last six months?

☐No

☐Yes (please state below any changes and also the approximate date at which they happened.)

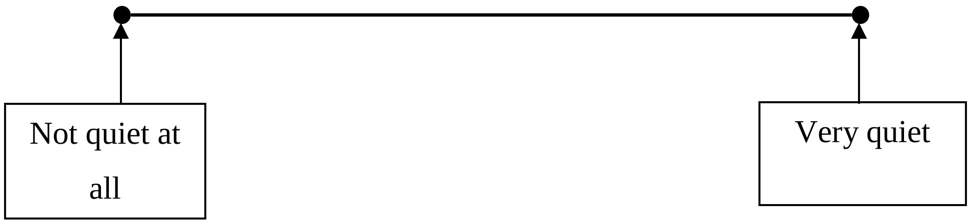
……
……
……
……
……

28. Please state the household composition

Number of adults:
……
……

Number of children and their age:
……
……
………..

29. How would you rate the quietness of your household? (please put a cross on the line to mark the rate)



YOUR CAT'S BEHAVIOUR IN THE LAST WEEK

Given below is a list of cat behaviours. For each behaviour, please record *on the first line* the *typical frequency* that your cat shows the behaviour.

On *the second line* please record, in the same way, the frequency of the same behaviour but just describing *your cat's behaviour during the last week*.

For example, if your cat typically shows a particular behaviour once a week or less, then this is very infrequent and so you would put a mark on the line closer to the left hand end. If, however, in the last week your cat has been showing this same behaviour several times a day, then…

☐Long lasting hiding (e.g. in boxes or hiding places, behind the sofa, under the bed)

Typical

Never Very

Last week

Never Very

☐Hissing or growling in any context (e.g. at you, others cats in the home, or a neighbour's cat)

Typical

Never Very

Last week

Never Very

☐Scratching objects, including its own scratch post

Typical

Never Very

Last week

Never Very

☐Scratching or biting people (owners or visitors)

Typical

Never Very

Last week

Never Very

☐Fighting with other cats (either with your own, if you own more than one cat, or other people's cats)

Typical

Never Very

Last week

Never Very

☐Lip licking or exaggerated swallowing without any food involved

Typical

Never Very

Last week

Never Very

☐Short sharp and rapid self-groom/ licking

Typical

Never Very

Last week

Never Very

☐Head shaking (refer to example)

Typical

Never Very

Last week

Never Very

☐Skin twitching or rippling (refer to example)

Typical

Never Very

Last week

Never Very

☐ Tail erected or body hair erected (refer to example)

Typical

Never Very

Last week

Never Very

☐Inappropriate toileting: spraying, defecating or urinating in the house

Typical

Never Very

Last week

Never Very

☐Social interactions with you (rubbing on your leg, hands, coming for a stroke, purring next to you or when stroked, sitting or lying next to you or on your knees, sleeping with you..)

Typical

Never Very

Last week

Never Very

☐Social interaction with other cats (rubbing on each other, grooming each other, sleeping in very close proximity, walking alongside one another)

Typical

Never Very

Last week

Never Very

☐Playing interaction with you or with a toy

Typical

Never Very

Last week

Never Very

☐Interacting with toys (on his own), feeding devices and/or any forms of enrichment

Typical

Never Very

Last week

Never Very